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ANNUAL REPORT OF THE
BOARD OF REGENTS OF

THE SMITHSONIAN INSTITUTION

SHOWING THE

OPERATIONS, EXPENDITURES, AND
CONDITION OF THE INSTITUTION
FOR THE YEAR ENDING JUNE 30

1914

WASHINGTON
GOVERNMENT PRINTING OFFICE
1915

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LETTER

FROM THE

SECRETARY OF THE SMITHSONIAN INSTITUTION,

SUBMITTING

THE ANNUAL REPORT OF THE BOARD OF REGENTS OF THE INSTITUTION FOR THE YEAR ENDING JUNE 30, 1914.

Smithsonian Institution,
Washington, December 15, 1914.

To the Congress of the United States:

In accordance with section 5593 of the Revised Statutes of the United States, I have the honor, in behalf of the Board of Regents, to submit to Congress the annual report of the operations, expenditures, and condition of the Smithsonian Institution for the year ending June 30, 1914. I have the honor to be,

Very respectfully, your obedient servant,

Charles D. Walcott, *Secretary.*

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ANNUAL REPORT OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION FOR THE YEAR ENDING JUNE 30, 1914.

SUBJECTS.

1. Annual report of the secretary, giving an account of the operations and condition of the Institution for the year ending June 30, 1914, with statistics of exchanges, etc.

2. Report of the executive committee of the Board of Regents, exhibiting the financial affairs of the Institution, including a statement of the Smithsonian fund, and receipts and expenditures for the year ending June 30, 1914.

3. Proceedings of the Board of Regents for the fiscal year ending June 30, 1914.

4. General appendix, comprising a selection of miscellaneous memoirs of interest to collaborators and correspondents of the Institution, teachers, and other engaged in the promotion of knowledge. These memoirs relate chiefly to the calendar year 1914.

THE SMITHSONIAN INSTITUTION

June 30, 1914.

Presiding officer ex officio.—WOODROW WILSON, President of the United States.
Chancellor.—EDWARD DOUGLASS WHITE, Chief Justice of the United States.
Members of the Institution:
  WOODROW WILSON, President of the United States.
  THOMAS R. MARSHALL, Vice President of the United States.
  EDWARD DOUGLASS WHITE, Chief Justice of the United States.
  WILLIAM JENNINGS BRYAN, Secretary of State.
  WILLIAM GIBBS MCADOO, Secretary of the Treasury.
  LINDLEY MILLER GARRISON, Secretary of War.
  JAMES CLARK MCREYNOLDS, Attorney General.
  ALBERT SIDNEY BURLESON, Postmaster General.
  JOSEPHUS DANIELS, Secretary of the Navy.
  FRANKLIN KNIGHT LANE, Secretary of the Interior.
  DAVID FRANKLIN HOUSTON, Secretary of Agriculture.
  WILLIAM COX REDFIELD, Secretary of Commerce.
  WILLIAM BAUCHOP WILSON, Secretary of Labor.
Regents of the Institution:
  EDWARD DOUGLASS WHITE, Chief Justice of the United States, Chancellor.
  THOMAS R. MARSHALL, Vice President of the United States.
  HENRY CABOT LODGE, Member of the Senate.
  WILLIAM J. STONE, Member of the Senate.
  HENRY FRENCH HOLLIS, Member of the Senate.
  SCOTT FERRIS, Member of the House of Representatives.
  MAURICE CONNOLLY, Member of the House of Representatives.
  ERNEST W. ROBERTS, Member of the House of Representatives.
  ANDREW D. WHITE, citizen of New York.
  ALEXANDER GRAHAM BELL, citizen of Washington, D. C.
  GEORGE GRAY, citizen of Delaware.
  CHARLES F. CHOATE, Jr., citizen of Massachusetts.
  JOHN B. HENDERSON, Jr., citizen of Washington, D. C.
  CHARLES W. FAIRBANKS, citizen of Indiana.
Executive committee.—(————), ALEXANDER GRAHAM BELL, MAURICE CONNOLLY.
Secretary of the Institution.—CHARLES D. WALCOTT.
Assistant secretary in charge of the National Museum.—RICHARD RATHBUN.
Chief clerk.—HARRY W. DORSEY.
Accountant and disbursing agent.—W. I. ADAMS.
Editor.—A. HOWARD CLARK.
Assistant librarian.—PAUL BROCKETT.
Property clerk.—J. H. HILL.

THE NATIONAL MUSEUM.

Keeper ex officio.—CHARLES D. WALCOTT, Secretary of the Smithsonian Institution.

Assistant secretary in charge.—RICHARD RATHBUN.

Administrative assistant.—W. DE C. RAVENEL.

Head curators.—WILLIAM H. HOLMES, LEONHARD STEJNEGER, G. P. MERRILL.

Curators.—R. S. BASSLER, A. HOWARD CLARK, F. W. CLARKE, F. V. COVILLE, W. H. DALL, CHESTER G. GILBERT, W. H. HOLMES, WALTER HOUGH, L. O. HOWARD, ALEŠ HRDLIČKA, FREDERICK L. LEWTON, GEORGE C. MAYNARD, G. P. MERRILL, GERRIT S. MILLER, JR., RICHARD RATHBUN, ROBERT RIDGWAY, LEONHARD STEJNEGER.

Associate curators.—J. C. CRAWFORD, W. R. MAXON, DAVID WHITE.

Curator, National Gallery of Art.—W. H. HOLMES.

Chief of correspondence and documents.—RANDOLPH I. GEARE.

Disbursing agent.—W. I. ADAMS.

Chief of exhibits (Biology).—JAMES E. BENEDICT.

Superintendent of construction and labor.—J. S. GOLDSMITH.

Editor.—MARCUS BENJAMIN.

Assistant librarian.—N. P. SCUDDER.

Photographer.—T. W. SMILLIE.

Registrar.—S. C. BROWN.

Property clerk.—W. A. KNOWLES.

Engineer.—C. R. DENMARK.

BUREAU OF AMERICAN ETHNOLOGY.

Ethnologist-in-charge.—F. W. HODGE.

Ethnologists.—J. WALTER FEWKES, J. N. B. HEWITT, F. W. HODGE, FRANCIS LA FLESCHE, TRUMAN MICHELSON, JAMES MOONEY, MATILDA COXE STEVENSON, JOHN R. SWANTON.

Special ethnologist.—LEO J. FRACHTENBERG.

Honorary philologist.—FRANZ BOAS.

Editor.—JOSEPH G. GURLEY.

Librarian.—ELLA LEARY.

Illustrator.—DE LANCEY GILL.

INTERNATIONAL EXCHANGES.

Chief clerk.—C. W. SHOEMAKER.

NATIONAL ZOOLOGICAL PARK.

Superintendent.—FRANK BAKER.

Assistant superintendent.—A. B. BAKER.

ASTROPHYSICAL OBSERVATORY.

Director.—C. G. ABBOT.

Aid.—F. E. FOWLE, JR.

Bolometric assistant.—L. B. ALDRICH.

REGIONAL BUREAU FOR THE UNITED STATES, INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE.

Assistant in charge.—LEONARD C. GUNNELL.

REPORT

OF THE

SECRETARY OF THE SMITHSONIAN INSTITUTION

CHARLES D. WALCOTT

FOR THE YEAR ENDING JUNE 30, 1914.

To the Board of Regents of the Smithsonian Institution:

GENTLEMEN: I have the honor to submit herewith a report on the operations of the Smithsonian Institution and its branches during the fiscal year ending June 30, 1914, including work placed by Congress under the direction of the Board of Regents in the United States National Museum, the Bureau of American Ethnology, the International Exchanges, the National Zoological Park, the Astrophysical Observatory, and the United States Bureau of the International Catalogue of Scientific Literature.

The general report reviews the affairs of the Institution proper and briefly summarizes the operations of its several branches, while the appendices contain detailed reports by the assistant secretary and others directly in charge of various activities. The reports on operations of the National Museum and the Bureau of American Ethnology will also be published as independent volumes.

THE SMITHSONIAN INSTITUTION.

THE ESTABLISHMENT.

The Smithsonian Institution was created an establishment by act of Congress approved August 10, 1846. Its statutory members are the President of the United States, the Vice President, the Chief Justice, and the heads of the executive departments.

THE BOARD OF REGENTS.

The Board of Regents consists of the Vice President and the Chief Justice of the United States as ex officio members, three Members of the Senate, three Members of the House of Representatives, and six citizens, "two of whom shall be resident in the city of Washington, and the other four shall be inhabitants of some State, but no two of them of the same State."

In regard to the personnel of the board, it becomes my sad duty to record the death on December 22, 1913, of Representative Irvin

S. Pepper, and of Senator Augustus O. Bacon, who died February 14, 1914. Representative Maurice Connolly has been appointed to succeed Mr. Pepper and Senator Henry French Hollis to succeed Senator Bacon. Representative Ernest W. Roberts has been appointed as successor to Representative John Dalzell, whose term of office as Member of Congress had expired.

The roll of Regents at the close of the fiscal year was as follows: Edward D. White, Chief Justice of the United States, Chancellor; Thomas R. Marshall, Vice President of the United States; Henry Cabot Lodge, Member of the Senate; Henry French Hollis, Member of the Senate; William J. Stone, Member of the Senate; Scott Ferris, Member of the House of Representatives; Maurice Connolly, Member of the House of Representatives; Ernest W. Roberts, Member of the House of Representatives; Andrew D. White, citizen of New York; Alexander Graham Bell, citizen of Washington, D. C.; George Gray, citizen of Delaware; Charles F. Choate, jr., citizen of Massachusetts; John B. Henderson, jr., citizen of Washington, D. C.; and Charles W. Fairbanks, citizen of Indiana.

At its meeting on January 15, 1914, the board filled a vacancy in the Executive Committee by the election of Hon. Maurice Connolly.

The annual meeting of the Board of Regents, adjourned from December 11, 1913, was held on January 15, 1914, and the proceedings of the meeting have been printed as usual for the use of the Regents, while such important matters acted upon as are of public interest are reviewed under appropriate heads in the present report of the secretary. The annual financial report of the Executive Committee has also been issued in the usual form, and a detailed statement of disbursements from Government appropriations under the direction of the Institution for the maintenance of the National Museum, the National Zoological Park, and other branches will be submitted to Congress by the secretary in the usual manner in compliance with the law.

GENERAL CONSIDERATIONS.

The "increase of knowledge" is one of the fundamental objects of the Smithsonian Institution, and one of the first acts of the Board of Regents in 1847 was to formulate a general plan of operations to carry out that purpose. Among the examples of lines of work for which appropriations were to be made from time to time were the following:

(1) System of extended meteorological observations for solving the problem of American storms.

(2) Explorations in descriptive natural history, and geological, mathematical, and topographical surveys, to collect material for the formation of a physical atlas of the United States.

(3) Solution of experimental problems, such as a new determination of the weight of the earth, of the velocity of electricity and of light, chemical analyses of soils and plants, collection and publication of articles of science accumulated in the offices of the Government.

(4) Institution of statistical inquiries with reference to physical, moral, and political subjects.

(5) Historical researches, and accurate surveys of places celebrated in American history.

(6) Ethnological researches, particularly with reference to the different races of men in North America; also explorations and accurate surveys of the mounds and other remains of the ancient people of our country.

It has been the aim of the Institution throughout its history to accomplish as much as practicable in all the fields of research above enumerated, and the secretaries of the Smithsonian have in their turn been chosen by the regents with that end in view. The first secretary, Professor Henry, was a physicist, and researches during his administration were largely in the domain of physics.

The present United States Weather Bureau is an outgrowth of the system of meteorological observations and warnings established by the Smithsonian Institution. In 1847 an appropriation was made "for instruments and other expenses connected with meteorological observations." The instruments thus secured were distributed throughout the country, and within two years the volunteer observers reporting to the Institution numbered about 400. In 1849 Henry realized the value of the electric telegraph as "a ready means of warning the more northern and southern observers to be on the watch for the first appearance of an advancing storm," and there was inaugurated a system of daily telegraphic weather reports, a system which was continued under the direction of the Institution until the beginning of the Civil War. On a large map in the Smithsonian building the weather over a considerable part of the country, according to reports received at 10 o'clock each day, was indicated by suitable symbols.

Under the second secretary, Professor Baird, biological science was one of the principal fields of research. It was during his administration that there was organized the United States Fish Commission for the study of the food fisheries of the United States, and Prof. Baird served as head of that commission until his death. The organization later became the United States Bureau of Fisheries of the Department of Commerce. Prof. Baird took a deep interest in the National Museum, and under his direction there was erected a building for the exhibition of the valuable collections acquired from the International Exhibition at Philadelphia in 1876.

Professor Langley, the third secretary, was both an astronomer and a physicist. But to his deep devotion to those professions may be added a broad view of the entire field of human knowledge. It was during the administration of Langley that the Astrophysical Observatory was established to carry forward researches begun by him many years before. And the National Zoological Park, largely the outgrowth of investigations on living animals under the direction of Assistant Secretary Goode, was likewise founded during Langley's administration. To Langley himself the world owes a debt for his discoveries of the principles of aerial navigation and for his demonstration to the world on May 6, 1896, by the successful flight of an experimental machine, that an aeroplane heavier than air could be propelled through the air by its own power.

It would be interesting, were this the proper place, to review some of the results of the many important researches and explorations by the Institution in the last 60 years. The influence of the Institution is world-wide; through its international exchange service alone it has been in correspondence with more than 60,000 individuals and learned societies in the United States and practically in every land on the globe. During its entire existence there has been an unbroken record of friendly intercourse with every agency devoted to the encouragement of learning.

The extent of the activities of the Institution is limited only by the amount of the funds available. During recent years its private income has been supplemented on several occasions by friends of the Institution who have generously provided the means for carrying on certain explorations and lines of research, but opportunities for further important work constantly arise which must be declined or temporarily held in abeyance. Some of the projects proposed are such as could not properly be carried on through Government appropriation, but which the Smithsonian Institution could readily undertake were the means available.

The Institution was founded by the bequest of James Smithson, and from time to time it has been the recipient of other bequests and of gifts of various sums, the largest of which was the gift of Mr. Thomas G. Hodgkins, establishing the Hodgkins Fund. The Smithsonian permanent fund now aggregates a little more than a million dollars. A number of bequests, now awaiting settlement, will eventually result in considerably increasing the present fund. Among these I may mention—

Poore bequest.—By the terms of the will of the late George W. Poore, of Lowell, Mass., who died December 17, 1910, the Smithsonian Institution becomes his residuary legatee. As mentioned in my 1910 report, the estate, estimated at about $40,000, is bequeathed under the condition that the income of this sum should be added to the principal until a total of $250,000 should have been reached, and that then the income only should be used for the purposes for which the Institution was created.

As a reason for making this bequest to the Smithsonian Institution Mr. Poore in his will says:

> I make this gift not so much because of its amount as because I hope it will prove an example for other Americans to follow, by supporting and encouraging so wise and beneficent an institution as I believe the Smithsonian Institution to be, and yet it has been neglected and overlooked by American citizens.

The affairs of this estate are being adjusted by the executor as rapidly as circumstances will permit.

Reid bequest.—In 1903 the Institution was informed of a proposed bequest to the Institution from Mr. Addison T. Reid, of Brooklyn, N. Y., to found a chair of biology in memory of the testator's grandfather, Asher Tunis. The bequest was subject to the condition that the income was to be paid in three equal shares to certain named legatees until their death, when the principal of the estate (then estimated at $10,000), with accumulations, was to come to the Institution. One of the beneficiaries having died, the trust created for her benefit, amounting to $4,795.91, was received by the Institution during the past year and deposited to the credit of the permanent fund in the United States Treasury.

Loeb bequest.—By the will of Morris Loeb, of New York City, the Smithsonian Institution is made a residual legatee and is to receive a one-tenth share of the estate remaining upon the death of the testator's wife. This legacy is to be used for the furtherance of knowledge in the exact sciences.

Morris Loeb, chemist, was born at Cincinnati May 23, 1863, and died October 8, 1912. He graduated from Harvard University in 1883 with the degree of A. B. and received the degree of Ph. D. from the University of Berlin in 1887 and Sc. D. from Union University in 1911. In 1891 he became professor of chemistry at the New York University. He was vice president of the American Chemical Society, and a member of the German Chemical Society and other scientific bodies.

Lucy Hunter Baird bequest.—Miss Baird, daughter of the late Spencer Fullerton Baird, Secretary of the Institution, died June 19, 1913. Besides giving to the National Museum and the Smithsonian Institution certain books, manuscripts, and other articles, the will of Miss Baird provides that upon the release of any portion of the trust estate by the death of the person entitled to the income thereof, said trust estate shall be given "to the Smithsonian Institution in trust as a fund to be known as 'the Spencer Fullerton Baird fund,' the interest shall be devoted, under the direction of the Smithsonian Institution to the expenses in whole or in part of a scientific exploration and biological research or for the purchase of specimens of natural objects or archæological specimens."

Chamberlain bequest.—In 1886 the National Museum received by bequest of Dr. Isaac Lea, of Philadelphia, an unrivaled collection of fresh-water mussels; and in 1894 a collection of gems and precious stones, also made by Dr. Lea, was bequeathed to the Museum by his daughter, Frances Lea Chamberlain, wife of Rev. Dr. Leander T. Chamberlain. Mrs. Chamberlain had taken a deep interest in her father's collections and had added materially thereto. Upon her death in 1894, Dr. Chamberlain assumed the trust and until his death in May, 1913, made large additions, particularly to the collection of gems and precious stones and in consequence of his gifts and collaboration was appointed honorary associate in mineralogy in the Museum.

In his will, Dr. Chamberlain bequeathed $25,000 to the Smithsonian Institution to be known as the "Frances Lea Chamberlain fund," the income of which shall be used for "promoting the increase and the scientific value and usefulness of the Isaac Lea collection of gems and gem material," and the additional sum of $10,000 as a fund, the income of which shall be used for promoting the scientific value and usefulness of the Isaac Lea collection of mollusks.

Sprague bequest.—Mr. Joseph White Sprague, of Louisville, Ky., died in Italy in June, 1900. His will provides that 85 per cent of the total income of the estate is to be distributed among certain devisees until their death, and then to several of their relatives for 20 years after the death of the last devisee, when the trust expires by limitation, and is to be paid to the Smithsonian Institution and to be known as "The Sprague Fund." Its purpose is to best promote the advancement of the physical sciences, and only one-half of each annual income is to be used, the other half to be added to the principal of the estate. In 1901, the estate was estimated to be worth $200,000.

Fitzgerald bequest.—The will of Mr. Riter Fitzgerald, of Philadelphia, who died in 1911, makes certain definite bequests and leaves all the rest, residue and remainder of the estate, to his executors in trust, the net income to be paid quarterly to his niece, and should she die without leaving a child or children, the principal of the estate and interest accrued thereon is to be given "to the United States National Museum of the Smithsonian Institution, Washington, D. C." This part of the estate is appraised at between $12,000 and $13,000.

FINANCES.

The permanent fund of the Institution and the sources from which it was derived are as follows:

Deposited in the Treasury of the United States.

Bequest of James Smithson, 1846	$515, 169. 00
Residuary legacy of James Smithson, 1867	26, 210. 63
Deposits of savings of income, 1867	108, 620. 37

Bequest of James Hamilton, 1875	$1,000	
Accumulated interest on Hamilton fund, 1895	1,000	
		$2,000.00
Bequest of Simeon Habel, 1880		500.00
Deposits from proceeds of sale of bonds, 1881		51,500.00
Gift of Thomas G. Hodgkins, 1891		200,000.00
Part of residuary legacy of Thomas G. Hodgkins, 1894		8,000.00
Deposit from savings of income, 1903		25,000.00
Residuary legacy of Thomas G. Hodgkins, 1907		7,918.69
Deposit from savings of income, 1913		636.94
Bequest of William Jones Rhees, 1913		251.95
Deposit of proceeds from sale of real estate (gift of Robert Stanton Avery), 1913		9,692.42
Bequest of Addison T. Reid, 1914		4,795.91
Deposit of savings from income Avery bequest, 1914		204.09
Total of fund deposited in the United States Treasury		960,500.00

OTHER RESOURCES.

Registered and guaranteed bonds of the West Shore Railroad Co., part of legacy of Thomas G. Hodgkins (par value)	42,000.00
Total permanent fund	1,002,500.00

With the aid of the first installment of $4,795.91 of a bequest from the late Addison T. Reid and a small deposit from savings of income from the Avery bequest, the permanent fund now, for the first time, exceeds $1,000,000.

That part of the fund deposited in the Treasury of the United States bears interest at 6 per cent per annum, under the provisions of the act organizing the Institution and an act of Congress approved March 12, 1894. The rate of interest on the West Shore Railroad bonds is 4 per cent per annum.

The income of the Institution during the year, amounting to $90,982.54, was derived as follows: Interest on the permanent foundation, $58,994.29; contributions from various sources for specific purposes, $17,554.20; first installment of a bequest from the late Addison T. Reid, $4,795.91; and from other miscellaneous sources, $9,638.14; all of which was deposited in the Treasury of the United States.

With the balance of $33,641.40 on July 1, 1913, the total resources for the fiscal year amounted to $124,623.94. The disbursements which are given in detail in the annual report of the executive committee, amounted to $94,063.81, leaving a balance of $30,560.13 on deposit June 30, 1914, in the United States Treasury and in cash.

The Institution was charged by Congress with the disbursement of the following appropriations for the year ending June 30, 1914:

International exchanges	$32,000
American Ethnology	42,000
Astrophysical Observatory	13,000

National Museum:	
Furniture and fixtures	$50,000
Heating and lighting	50,000
Preservation of collections	300,000
Books	2,000
Postage	500
Building repairs	10,000
Bookstacks for Government bureau libraries	15,000
National Zoological Park	100,000
Readjustment of boundaries, National Zoological Park	107,200
International Catalogue of Scientific Literature	7,500
Total	729,200

In addition to the above specific amounts to be disbursed by the Institution, there was included under the general appropriation for public printing and binding an allotment of $76,200 to cover the cost of printing and binding the annual report and other Government publications issued by the Institution, and to be disbursed by the Public Printer.

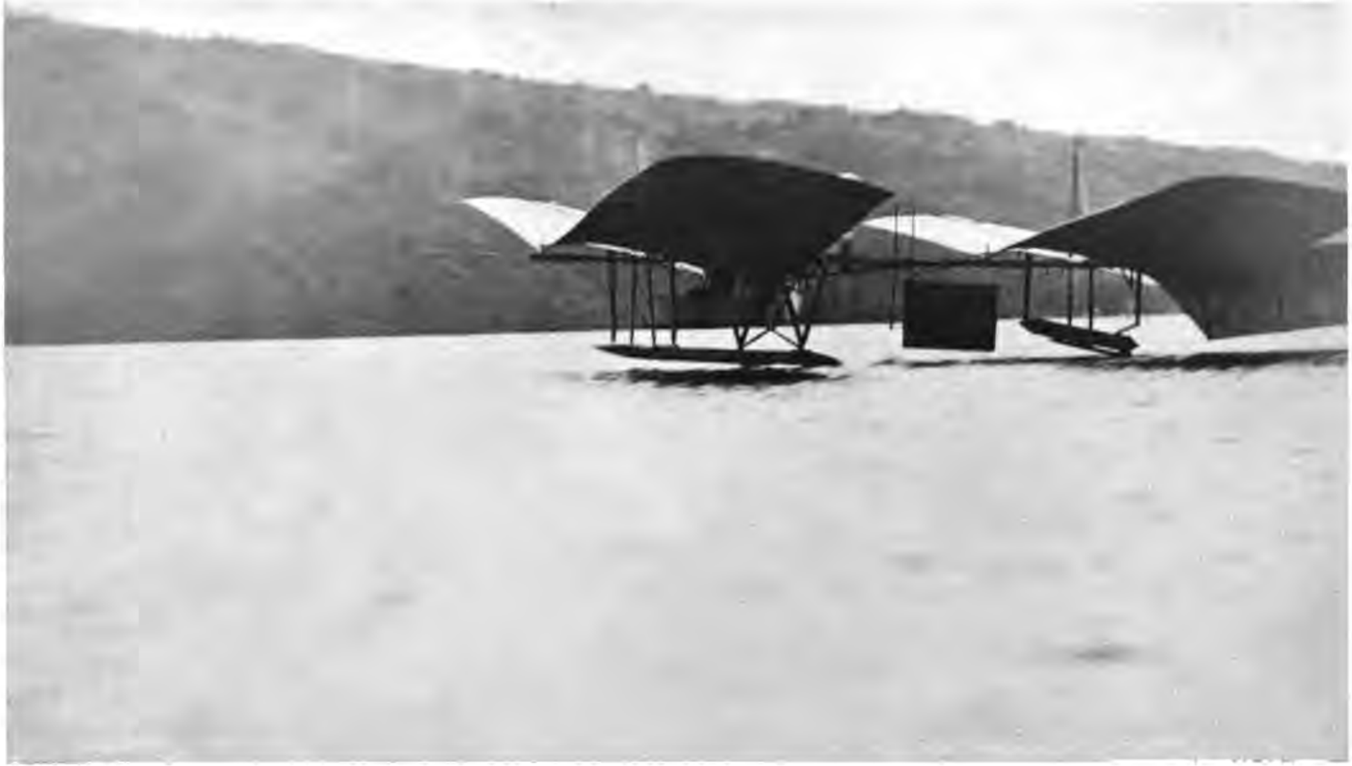
RESEARCHES AND EXPLORATIONS.

During the past year the Institution has continued to carry on investigations in various lines throughout the world by means of small allotments from its funds. It has also accomplished a great deal in the way of exploration and research through the generosity of friends of the Institution, who have contributed funds for special work or provided opportunities for participation in explorations which they had undertaken personally or through the aid of others. Each year, however, the Institution is obliged to forego opportunities for important investigations through lack of sufficient funds.

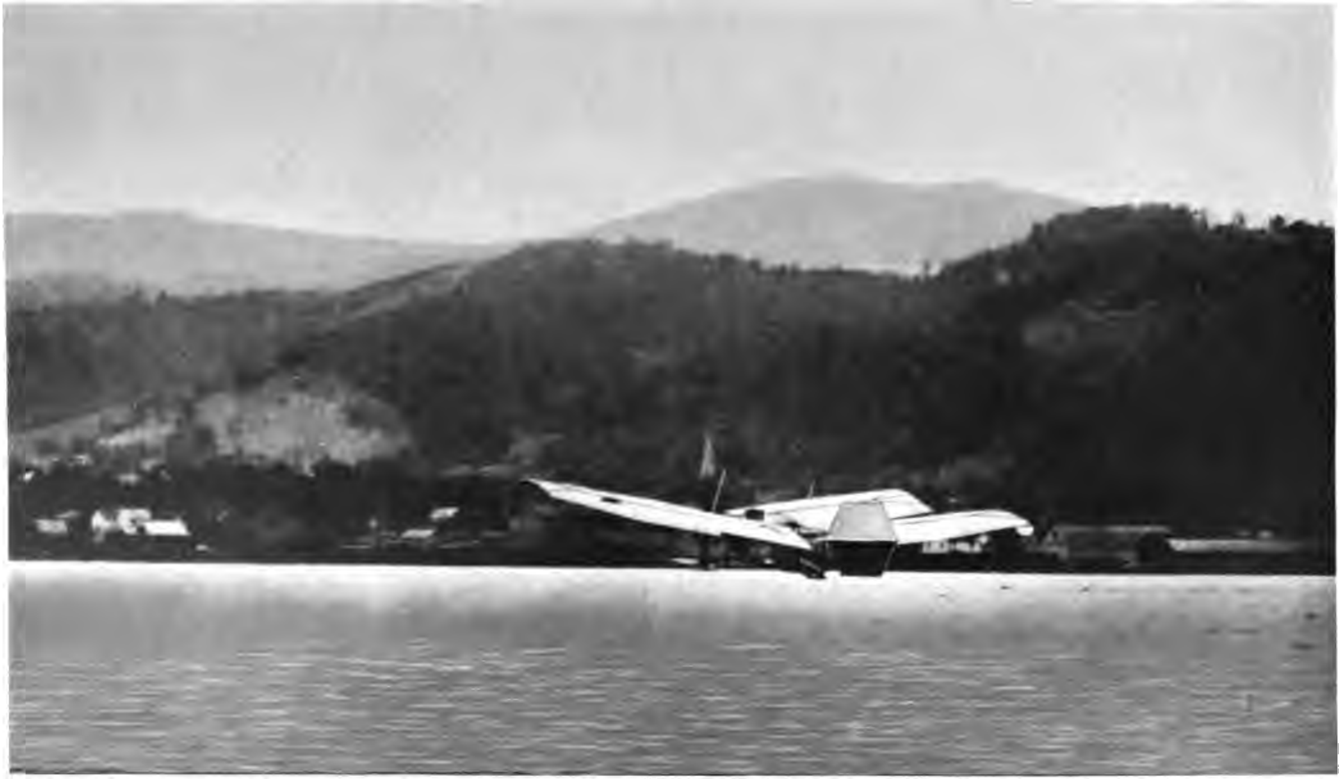
I can here only briefly mention some of the work in progress under the Smithsonian Institution proper during the past year, while accounts of activities connected with the Astrophysical Observatory, the Bureau of American Ethnology, and the United States National Museum are given in other parts of this report by those in direct charge of those branches of the Institution.

THE LANGLEY AERODYNAMICAL LABORATORY.

By resolution of the Regents on May 1, 1913, the secretary was authorized to reopen the Smithsonian Institution laboratory for the study of aerodynamics and to be known as the Langley Aerodynamical Laboratory. The functions of the laboratory were defined to be the study of the problems of aerodromics, particularly those of aerodynamics, with such research and experimentation as may be necessary to increase the safety and effectiveness of aerial locomotion for the purposes of commerce, national defense, and the welfare of man.



LANGLEY MAN-CARRYING AERODROME (BUILT 1898-1903) EQUIPPED WITH FLOATS, IN FLIGHT OVER LAKE KEUKA, HAMMONDSPORT, N. Y., JUNE 2, 1914.



LANGLEY MAN-CARRYING AERODROME (BUILT 1898-1903) EQUIPPED WITH FLOATS, IN FLIGHT OVER LAKE KEUKA, HAMMONDSPORT, N. Y., JUNE 2, 1914.

The Regents also authorized the secretary to appoint an advisory committee; to add, as means are provided, other laboratories and agencies; to group them into a bureau organization; and to secure the cooperation with them of the Government and other agencies.

In accordance with the above general plan an advisory committee was organized at a meeting convened at the Institution on May 23, 1913. The official status, organization, agencies, resources, and facilities of this committee were set forth in a statement in my last report.

The first year's work of the laboratory was to arrange a comprehensive program of operations, devise ways and means of carrying on investigations and publishing reports, conduct such active experiments as were possible with the means immediately available, and to secure and arrange in the library the best aeronautical literature.

The reports of the committee thus far published have appeared as individual papers in the Smithsonian Miscellaneous Collections. The first of these recounts the organization of the advisory committee and the resources of the Langley laboratory. The first technical publication sets forth the results of experiments made at the model tank at the Washington Navy Yard. Another report describes the organization and equipment of the leading aeronautical laboratories of England, France, and Germany. Some of the reports of the committee are as yet confidential or incomplete. The library has been furnished with the chief aeronautic periodicals and the best books thus far published.

The rehabilitation and successful launching of the Langley aeroplane (called "aerodrome" by Prof. Langley), constructed over a decade ago, was accomplished in May, 1914. The machine was shipped from the Langley laboratory to the Curtiss aeroplane factory in April. It was recanvassed and provided with hydroaeroplane floats, and was launched on Lake Keuka on May 28. With Mr. Glenn H. Curtiss as pilot it ran easily over the water, rose on level wing, and flew in steady poise 150 feet. Subsequent short flights were made in order to secure photographs of the craft in the air. Then Mr. Curtiss was authorized, in order to make prolonged flights without overtaxing the bearings of the Langley propulsion fixtures, to install in its place a standard Curtiss motor and propeller. At the close of the fiscal year the experiments were still making satisfactory progress.

The tests thus far made have shown that the late Secretary Langley had succeeded in building the first aeroplane capable of sustained free flight with a man. It is hoped that further trials will disclose the advantages of the Langley type of machine. It may be recalled that this man-carrying aeroplane was begun in 1898 for the War

Department, and in the interest of the national defense. It was built on the design of the model machine which, on May 6, 1896, first demonstrated to the world that an aeroplane heavier than air could be propelled through the air by its own power. The large machine was completed in 1903, but its actual flight was at that time hindered by injuries sustained through defects in the launching apparatus.

The numerous and comprehensive aerotechnical investigations planned for the Langley laboratory can be successfully carried out only when increased funds are available. Properly equipped and endowed, the laboratory would serve as a national aeronautical institute suitable for conducting the aerotechnical investigations and tests required by the Government and the aeronautical industries of this country.

GEOLOGICAL EXPLORATIONS IN THE CANADIAN ROCKIES.

In continuation of my previous geological researches in the Canadian Rockies, I revisited during the field season of 1913 the Robson Peak district, in British Columbia and Alberta, and the region about Field, British Columbia. At the latter place I met the members of the International Geological Congress.

On this trip Robson Peak was approached from the west side in order to study the local geological section, one of the finest in the world. From the west foot of Robson Peak, Whitehorn Peak rises on the north to a height of 7,850 feet above Lake Kinney, and on the east the cliffs of Robson rise tier above tier from the surface of the lake to the summit of the peak, a vertical distance of 9,800 feet.

From beneath the base of the mountain at Lake Kinney the strata curve gently outward, so that upwards of 4,000 feet in thickness of beds that are beneath Robson Peak are exposed in their extension to the west and south.

Owing to exceptionally good climatic conditions the season of 1913 proved unusually favorable for studying Robson Peak. Frequently in the early morning the details of the snow slopes and bedded rocks on the summit of the peak were beautifully outlined, but toward evening the mists, driven in from the warm currents of the Pacific, 300 miles away, shrouded the mountain from view.

From the west slopes of Titkana Peak, east of the great Hunga Glacier, a wonderful view is obtained of the snow fields and falling glaciers east and north of Robson Peak. The glacial streams come tumbling down the slopes and often disappear beneath the glacier to reappear at its foot with the volume of a river.

At Field, British Columbia, work was continued at the great middle Cambrian fossil quarry, where a large collection of specimens was secured. It was necessary to do much heavy blasting to reach the finest fossils which occur in the lower layers of rock.

The collection of 1913 contains a number of very important additions to this ancient fauna and many fine specimens of species found in 1912. A report on these collections is now in preparation.

An illustrated account of my previous exploration in the Robson Peak district was published in the Smithsonian Miscellaneous Collections, Vol. 57, No. 12, and a paper with panoramic view, entitled "The Monarch of the Canadian Rockies," appeared in the National Geographic Magazine, May, 1913. Three other reports of my studies were published in the Smithsonian Miscellaneous Collections, entitled "New Lower Cambrian Subfauna," "*Dikelocephalus* and other genera of the Dikelocephalinæ," and "The Cambrian Faunas of Eastern Asia." A report on "The Cambrian and its Problems in the Cordilleran Region" is now in press in a new volume of the Dana commemorative course at Yale University. The investigations discussed in this paper were continued in a report, "Pre-Cambrian Algonkian Algal Flora," in the Smithsonian Miscellaneous Collections, and preparations were made for further study of the subject in the Rocky Mountains of Montana during the field season of 1914. This was successfully carried out with the acquisition of several tons of specimens.

GEOLOGIC HISTORY OF THE APPALACHIAN VALLEY IN MARYLAND.

Dr. R. S. Bassler, of the National Museum, spent a month during the summer of 1913 in the Appalachian Valley of Maryland and the adjoining States, studying the postpaleozoic geologic history of the region, as indicated by the present surface features. His studies, which were under the joint auspices of the United States National Museum and the Maryland Geological Survey, were in continuation of work carried on during the previous summer, when the sedimentary rocks of the region were mapped in detail.

Since Carboniferous times western Maryland has been above the sea, and its rocks have accordingly been subjected to a long period of aerial erosion. During Jurassic time the area remained stationary for so long a period that the surface of the land in the Appalachian province was reduced to a rolling plain. Later uplift raised this plain still higher above sea level, and in Maryland only remnants of the old surface are preserved in the flat sky line of the highest mountains. This ancient plain, or Schooley peneplain, as it is termed, is well preserved on the top of the Blue Ridge.

A second great period of erosion occurred in early Tertiary times, the effects of which were chiefly in the Appalachian Valley proper, where the erosion is indicated by a pronounced plain at an elevation of about 750 feet. This plain was formed only on the softer Paleozoic rocks, and, because of its prominence near Harrisburg, Pa., is known as the Harrisburg peneplain. Conococheague Creek traverses the Harrisburg peneplain in Maryland, and has dissected it considerably, but the even sky line of the ancient plain is still clearly evident.

Other factors in the geologic history of Maryland are recorded in the well-defined gravel terraces along the major streams of the area and in great alluvial fans of large and small bowlders, spreading out at the foot of the larger mountains and sometimes reaching a depth of 150 feet.

PLEISTOCENE CAVE DEPOSIT IN MARYLAND.

As the results of a further examination of the Pleistocene cave deposit near Cumberland, Md., by Mr. J. W. Gidley, of the National Museum, many new forms were added to the collection, and much better material obtained of several species represented only by fragments of jaws in the first collection. The series now includes more than 300 specimens, representing at least 40 distinct species of mammals, many of which are extinct. Among the better preserved specimens are several nearly complete skulls and lower jaws. The more important animals represented are two species of bears, two species of a large extinct peccary, a wolverine, a badger, a martin, two porcupines, a woodchuck, and the American elandlike antelope.

Other species represented by more fragmentary material include the mastodon, tapir, horse, and beaver, besides several species of the smaller rodents, shrews, bats, and others.

This strange assemblage of fossil remains occurs hopelessly intermingled and comparatively thickly scattered through a more or less unevenly hardened mass of cave clays and breccias, which completely filled one or more small chambers of a limestone cave, the material, together with the bones, evidently having come to their final resting place through an ancient opening at the surface a hundred feet or more above their present location. The deposit is exposed at the bottom of a deep railroad cut which first brought to light this ancient bone deposit and incidentally made access to the fossils comparatively easy.

GEOLOGICAL SURVEY OF PANAMA.

A statement was made in my report for last year that an allotment had been made from the Institution's funds toward the expenses of an investigation of the geology of Panama. This work is in progress under the joint auspices of the Isthmian Canal Commission, the United States Geological Survey, and the Smithsonian Institution. The general plan includes a systematic study of the physiography, stratigraphy and structural geology, geologic history, geologic correlation, mineral resources (including coal, oil, and other fields), petrography and paleontology of the Canal Zone, and of as much of the adjacent areas of the Isthmian region as is feasible.

Upon the completion of the work the Institution will print a general account of the results, and later there will be published a detailed report of the geological data of the Isthmus and adjoining regions.

VERTEBRATE FOSSIL REMAINS IN MONTANA.

During the summer of 1913 Mr. Charles W. Gilmore, of the National Museum, headed an expedition for the purpose of obtaining a representative collection from northwestern Montana.

A camp was established on Milk River, on the Blackfeet Indian Reservation, and four weeks were spent there in collecting, the work being confined entirely to the Upper Cretaceous (Belly River beds) as exposed in the bad lands for 10 miles along this stream. The camp was then moved some 50 miles south on the Two Medicine River, and two weeks were spent working in the same geological formation. Between 500 and 600 separate fossil bones were obtained, many of them of large size. The most notable discovery was a new Ceratopsian or horned dinosaur, the smallest of its kind known. There were portions of five individuals of this animal recovered, representing nearly all parts of the skeleton, making it possible to mount a composite skeleton for exhibition. Although Ceratopsian fossils were first discovered in the Rocky Mountain region in 1855, and portions of a hundred or more skeletons have been collected, this is the first individual to be found having a complete articulated tail and hind foot. It thus contributes greatly to our knowledge of the skeletal anatomy of this interesting group of extinct reptiles.

Another find was a partial skeleton of one of the Trachodont or duck-billed dinosaurs recently described from specimens obtained in Canada, and its discovery in Montana greatly extends its known geographical and geological range. Less perfect skeletons of carnivorous and armored dinosaurs, turtles, crocodiles, and ganoid fishes were also obtained.

FOSSIL ECHINODERMS IN ILLINOIS.

The special field explorations maintained by Mr. Frank Springer, associate in paleontology in the United States National Museum, were continued during the season of 1913 by his private collector, Frederick Braun. The purpose of these explorations is to obtain additional material for use in Mr. Springer's monographs upon the fossil crinoidea, now in course of preparation, but they also result in important accessions of excellent specimens for the completion of the exhibition series in the halls of Invertebrate Paleontology in the National Museum.

The investigations of the past summer were confined to the Kaskaskia rocks of Monroe and Randolph Counties, Ill. They were systematically carried on in connection with the geological work for the State of Illinois, in progress at the same time under the direction of Prof. Weller, in order to have the benefit of accurate determinations of the horizons from which the collections were made, with reference to the several subordinate formations into which the Kaskaskia of that region is divided. In this way it was hoped to correct some confusion as to the stratigraphic relation of a number of species described in the geological reports of Illinois and Iowa. The operations were successful in this respect, and at the same time six large boxes of fine specimens were obtained. Among the specimens there are a number of slabs covered with crinoids not hitherto found in that formation in an excellent state of preservation, a portion of one slab containing 22 specimens of 9 different species.

MOLLUSCAN FAUNA OF VIRGINIA COAST.

Mr. John B. Henderson, jr., a member of the Board of Regents of the Institution, and Dr. Bartsch, of the National Museum, visited the Atlantic shore of Accomac County, Va., which had heretofore received little attention from collectors.

The chief objects of this trip were to determine of just what elements the molluscan fauna consisted; to see how many, if any, species of southern range lapped over from Hatteras, and what northern species still persisted in this faunal area. The collectors were fortunate in their somewhat haphazard choice of a locality, for they encountered at Chincoteague a greater variety of stations than can probably be found at any other point along this section of the coast. Here there are interior sounds of very considerable extent which are very shallow (4 to 12 feet), more or less thickly sown with oyster beds and with patches of eel grass, the bottom ranging from hard sand through varying degrees of hard clay to soft mud.

They found also the unusual feature of a bight or protected cove formed by the southward drift at the southern end of Assateague Island, protected from heavy wave action by a long, curved sand spit. This bight has a soft mud bottom, with a temperature possibly 8° less than that of the open sea. The mud brought up with the dredge seemed almost icy to the touch. This condition is probably produced by cold springs seeping through the floor of the bight. This colder water of the bight yielded to their dredge *Yoldia limatula*, large and fine, and *Nucula proxima*, whereas just around the protective spit of sand, on the ocean side, they found dead Terebras of two species, some young *Busycon perversa*, and a valve of *Cardium robustum*—a somewhat startling association of species.

Then there was the open sea, which here presumably differs in no manner from other open-sea stations along the 200 miles or more of this coast. The bottom drops off very gradually to the edge of the continental shelf, some 75 or 100 miles out. The open-sea stations which they occupied were, as might be expected, very poor. The smooth, hard sand bottom seemed almost barren of life, and the softer patches that were explored contained only many dead shells, mostly small bivalves. The work in the open sea was scarcely a good test, although they made probably 20 hauls, reaching out from the shore some 4 or 5 miles, but the chart soundings indicated more promising areas of pebbly bottom a few miles beyond what they considered the safety zone for a small motor boat.

The inner waters of the sound were found to be unexpectedly rich in molluscan life, the species, for the most part, not having been taken outside or in the bight.

EXPEDITION TO DUTCH EAST BORNEO AND CASHMERE.

In continuation of the exploration and collection carried on through the generosity of Dr. W. L. Abbott, by Mr. H. C. Raven, in Dutch East Borneo it may be said that the work is going forward with excellent results. Dr. Abbott is continuing his personal explorations in Cashmere and has forwarded some valuable specimens of mammals, including a queer little silvery gray shrew about 74 millimeters long, and a magnificent snow leopard, with its complete skeleton. In Baltistan, northwestern Cashmere, Dr. Abbott secured about 289 skins, which have been presented to the National Museum. After a sojourn in England he expected to return to Cashmere and march to Ladak. He also intended to visit Nubra and go east along the frontier to the Dipsang Plains, where he hoped to secure specimens of a certain vole from Kara Korum Pass, as well as the little Tibetan fox, known to the Cashmere furriers as the "king fox."

LIFE ZONES IN THE ALPS.

Aided by a small grant from the funds of the Institution, Dr. Stejneger, head curator of biology in the National Museum, visited the eastern Alps toward the close of the last fiscal year, to make further observations toward a determination of the limits of the life zones, which in that part of Europe might correspond to those established in North America. That a system of such life zones exists in Europe has long been more or less vaguely stated by authors, but although a definite correlation was established by Dr. Stejneger and Mr. Miller in 1904, certain points, especially the interrelation of the zones corresponding to the so-called Canadian and Hudsonian life zones in America, were greatly obscured by the long-continued interference of man and animals with nature, such as the grazing of cattle in the high Alps, deforestation, and more recently, artificial reforestation.

It was thought that the eastern Alps might show more primitive conditions. Dr. Stejneger visited the mountain region between Switzerland and the head of the Adriatic. Arrived at the town of Bassano, at the foot of the Venetian Alps, he began to study the life zones of the Val Sugana and the plateau of the Sette Comuni from that point. This plateau descends abruptly to the Venetian plain on the south, while to the east and north it is separated from the mass of the eastern Alps by the Val Sugana, or the valley of the River Brenta, and on the west by the lower part of the valley of the Adige, or Etsch. It is intersected by the boundary line between Italy and Austrian Tyrol.

He made a series of excursions from Bassano, Levico, and Trento as successive headquarters, during which time he completely circled the territory, and crossed the plateau once on foot. He was able to trace the boundaries of the Austral life zones in considerable detail, as well as to gather data which connect with the previous correlation of these zones in the western Alps and with the corresponding zones in North America. It was found that the bottom of the entire Val Sugana belongs to the upper Austral zone. Owing to the rainy and inclement weather the results were less satisfactory in the higher regions, though some important data corroborating previous conclusions were obtained.

Observations were also made on the Etsch Valley in Tyrol, from Trento to Schlanders, and on its tributary, the Eisak, from Bozen to its source on the Brenner Pass.

The elaboration of the detailed observations will be incorporated with a general report on the biological reconnoissance of the western Alps.

RESEARCHES UNDER HARRIMAN TRUST FUND.

Dr. C. Hart Merriam continued during the year to carry on certain natural history and ethnological investigations provided for by a special trust fund established by Mrs. E. H. Harriman for that purpose. His principal work during the year was on the big bears of America, a group he has been studying for more than 20 years and concerning which he now has a monograph in preparation. In furtherance of this study, specimens have been placed at his disposal by numerous sportsmen and hunters and by the larger museums of the United States and Canada. In the course of his investigations a transcontinental line was run across the country to the coast of California by which the easternmost limits of range were determined for a number of species of mammals, birds, reptiles, and plants. And while traversing Utah and Nevada several remote tribes of Indians were visited, particularly the Gosinte, from whom a long-needed vocabulary was obtained.

ANTHROPOLOGICAL RESEARCH IN EASTERN ASIA.

For the extension of researches in eastern Asia, in continuation of anthropological investigations carried on in Siberia and Mongolia under the direction of the Institution in 1912, an allotment has been made from the Smithsonian fund for work during the next fiscal year and for a limited period thereafter. The plan of operations includes a thorough study of the peoples of the eastern coast of Asia, Manchuria, Mongolia, Tibet, and Siberia, among whom it is believed lies the secret of the origin of the American Indian. Investigations thus far made by Dr. Hrdlička in behalf of the Institution indicate, he says, "that there exist to-day over large parts of eastern Siberia and in Mongolia, Tibet, and other regions in that part of the world numerous remains which now form constituent parts of more modern tribes or nations, of a more ancient population (related in origin, perhaps, with the latest paleolithic European), which were physically identical with, and in all probability gave rise to, the American Indian."

In a pamphlet on Smithsonian Explorations in 1913 a number of other biological and anthropological investigations are described.

RESEARCHES UNDER THE HODGKINS FUND.

The Hodgkins fund was established in 1891 by a gift of $200,000 from Mr. Thomas George Hodgkins, of Setauket, N. Y. By subsequent gifts during his life and through sums received from Mr. Hodgkins's estate, of which the Institution was made the residuary legatee, the fund has increased to about $250,000. It was stipulated by the donor that the income of $100,000 of his gift should be devoted to the increase and diffusion of more exact knowledge in regard to the nature and properties of atmospheric air in connection with the welfare of man. He indicated his desire that researches be not limited to sanitary science, but that the atmosphere be considered in its widest relationship to all branches of science, referring to the experiments of Franklin in atmospheric electricity and the discovery of Paul Bert in regard to the influence of oxygen on the phenomena of vitality as germane to his foundation. To stimulate researches in these directions the Institution offered a prize of $10,000 for a paper embodying some new and important discovery in regard to the nature and properties of atmospheric air, which was awarded in 1895 to Lord Rayleigh and Prof. William Ramsay, of London, for the discovery of argon, a new element in the atmosphere. Another prize of $1,000 for the best popular treatise on atmospheric air was awarded to Dr. Henry de Varigny, of Paris, from among 229 competitors in the United States, France, Germany, England, Scotland, Ireland, Italy, Russia, Austria-Hungary, Norway, Denmark, Finland, Bohemia, Bavaria, Servia, Switzerland, Spain, India, Canada, Mexico, and Argentina. Numerous investigations on the "composition of expired air and its effects upon animal life," in "atmospheric actinometry," the "air of towns," "animal resistance to disease," "experiments with ionized air," "the ratio of specific heats," and kindred topics have been carried on with the aid of grants from the Hodgkins fund. Researches have likewise been aided in connection with the temperature, pressure, radiation, and other features of the atmosphere at very high altitudes, extending during the past year to more than 45,000 feet, and many other lines of investigation have been carried on, through all of which it is believed that valuable knowledge has been acquired by which the welfare of man has been advanced.

Under a grant from the Hodgkins fund Mr. A. K. Ångström carried on some observations in California during the past year for the purpose of measuring nocturnal radiations at different altitudes ranging from below sea level to the summit of Mount Whitney, 4,420 meters (14,502 feet). Some of the results attained by Mr. Ångström and work in connection therewith are discussed by Dr. C. G. Abbot in his report as director of the Astrophysical Observatory.

A grant was also made to Mr. Ångström to enable him to measure the "nocturnal radiation"—that is, loss of heat to space during the total eclipse of the sun August 21, 1914, in the north of Sweden.

In connection with the International Congress on Tuberculosis held in the National Museum in 1908 the Institution offered a Hodgkins fund prize of $1,500 for the best treatise on "the relation of atmospheric air to tuberculosis." About a hundred papers were submitted, and after an exhaustive examination by the advisory committee the award has now been made and the prize divided equally between Dr. Guy Hinsdale, of Hot Springs, Va., and Dr. S. Adolphus Knopf, of New York, for their essays on the topic stated.

Dr. Hinsdale's essay was recently published at the expense of the Hodgkins fund, the public demand for the work requiring the printing of a second edition. In discussing the general treatment of the disease, the essayist has special reference to the effect of the atmospheric air and the value of various climates in relation to tuberculosis. In conclusion the author says:

> We believe that climate may be utilized as an adjuvant of great value for carrying out the hygienic, dietetic treatment of all forms of tuberculosis and many other diseases. * * * The first place must be assigned to an abundance

of air, which is as nearly as possible bacteriologically and chemically pure. * * * Only at the sea or at the highest elevations do we find air really pure, but we can approximate it by living out of doors.

* * * Probably the best combination is a low humidity and a moderately cool temperature; the average tuberculosis patient makes his best gains after August 1 and in subsequent cold, dry weather when such conditions prevail. * * *

The old idea about equability of temperature, at least between the temperature of midday and midnight, is not of great importance; all mountainous stations show great variations in this respect. Some variability tends to stimulate the vital activities, but in older people and those who are feeble great variability is a disadvantage.

As far as altitude is concerned it probably has not, per se, any great influence; certainly, to my mind, not so much as we used to think. However, altitude is incidentally associated with mountain life or life on the plains, with more sun, less moisture, and scattered population.

* * * Surgical tuberculosis is always favorably influenced by a seashore residence suitably chosen. * * * Constant outdoor life in all weather works miraculous cures after the most formidable operations for bone tuberculosis, and in many cases renders them wholly unnecessary in patients whose physical condition on admission was most unpromising.

SMITHSONIAN TABLE AT NAPLES ZOOLOGICAL STATION.

In the interest of American biologists who may desire to study marine life under exceptionally favorable facilities, the Institution has for more than 20 years maintained a table at the Naples Zoological Station. Investigators are assigned the use of this table for stated periods on the recommendation of an advisory committee appointed for the purpose. During the past year the table has been utilized by Mr. Reynold A. Spaeth, a student of Harvard University, who pursued studies in experimental physiology; Dr. T. S. Painter, graduate of Yale University, for work on an experimental cytological problem; and Prof. Edwin C. Starks, of Stanford University, for an investigation of the bones and muscles of the mandible of fishes.

RESEARCH CORPORATION.

In February, 1912, the Research Corporation was organized under the laws of New York as a means for furthering scientific and technical research. Its principal object is—

> to acquire inventions and patents and to make them more available in the arts and industries, while using them as a source of income, and, second, to apply all profits derived from such use to the advancement of technical and scientific investigation and experimentation through the agency of the Smithsonian Institution and such other scientific and educational institutions and societies as may be selected by the directors.

No dividends are to be paid, and the entire net profits are to be devoted to research. The Smithsonian Institution is interested in the management of this corporation through the membership of the secretary in its board of directors, which is composed of business and professional men, many of whom have had experience in large industrial and mining enterprises, and it is provided in the certificate of incorporation that the Smithsonian Institution may receive funds for research and experimentation.

The chief assets of the corporation at present are the Cottrell patents relating to the precipitation of dust, smoke, and chemical fumes by the use of electrical currents. Dr. F. G. Cottrell, the inventor and donor of these patents, has described their operation and advantages and the progress thus far made in their installation in an article printed in the Smithsonian Report for 1913.

A number of other patents in various fields of industry have been offered by officers of the Government and scientific institutions, as well as by manufacturing corporations holding patents not available for their own purposes, and undoubtedly there are many others, both in this country and abroad, who will be glad to have their inventions utilized for the benefit of scientific research.

AMERICAN SCHOOL OF ARCHEOLOGY IN CHINA.

In my last report mention was made of the proposed establishment of an American school of archeology in China. The objects of the school as proposed are: (1) To prosecute archeological research in eastern China; (2) to afford opportunity and facilities for investigation to promising and exceptional students, both foreign and native, in Asiatic archeology; and (3) to preserve objects of archeological and cultural interest in museums in the countries to which they pertain in cooperation with existing organizations, such as the Société d'Ankor, etc.

The management of the affairs of the school is placed in the hands of an executive committee of five, consisting of Dr. Charles D. Walcott, Secretary of the Smithsonian Institution; Mr. Charles Henry Butler, reporter of the United States Supreme Court; Prof. F. W. Shipley, of St. Louis; Mr. Charles L. Freer, of Detroit; and Mr. Eugene Meyer, jr., of New York. The general committee consists of 16 gentlemen especially interested in archeological research in China, with Dr. Walcott as chairman and Mr. Butler as secretary. A preliminary survey in the Chinese Republic for the information of the general committee in considering the permanent organization of the proposed school has been made, and the committee will later be called together for further consultation.

PUBLICATIONS.

Of new publications there was issued by the Smithsonian Institution and its branches during the year a total of 6,807 printed pages, with 834 plates of illustrations. The aggregate distribution was 202,671 copies of pamphlets and bound volumes.

One of the principal functions of the Institution, "the diffusion of knowledge," is accomplished through its publications, which record results of original researches, accounts of explorations, the progress achieved in science and industry, and general information in all branches of human knowledge believed to be of value to those interested in the promotion of science and in the welfare of man. The series of "Contributions to Knowledge" in quarto form, and the "Miscellaneous Collections," in octavo, are printed in limited editions at the expense of the Institution and distributed chiefly to certain large libraries throughout the world where they are available for public reference. The Annual Report, however, is provided for by congressional appropriations, and the edition is great enough to permit its wide distribution. Besides the official report of the Board of Regents and the secretary of the general operations of the Institution during the year, there is included in the Smithsonian Report a general appendix containing 30 or more original or selected papers illustrating the more remarkable and important developments in scientific discovery.

In addition to the three series of works above mentioned pertaining to the Institution proper, there are issued under its direction (*a*) the Annual Report, the Proceedings, and the Bulletins of the National Museum, including the Contributions from the National Herbarium; (*b*) the Annual Report and Bulletins of the Bureau of American Ethnology; and (*c*) the Annals of the Astrophysical Observatory, all of which are public documents printed through annual allotments by act of Congress.

Smithsonian Contributions to Knowledge.—The chief characteristic of memoirs contained in the Contributions to Knowledge is that they are discussions of extensive original investigations constituting important additions to knowledge. Since the establishment of this series in 1848 there have been published about 150 of these memoirs in 35 quarto volumes. The most recent of these, reviewed in my last report, was the "Langley Memoir on Mechanical Flight," recording the experiments of the late Secretary Langley, resulting in his successful demonstration of the practicability of aerial navigation with machines heavier than the air.

Smithsonian Miscellaneous Collections.—Thirty-six papers in this series were issued during the year, forming parts of seven volumes, as enumerated in Appendix 8. They included some articles by your secretary, describing further results of his studies of Cambrian fossils, and papers on the usual wide range of biological, geological, and anthropological topics. In this series are included the Smithsonian tables, which have become standard works of reference.

In 1852 the Institution published the first edition of the Smithsonian meteorological tables, which were so widely used by physicists during the next 40 years that it was decided to publish three sets of tables, independent of one another, but forming a homogenous series. The first of the new series, Smithsonian Meterological Tables, was published in 1893; revised editions were issued in 1896, 1897, and 1907, and another revised edition is now under consideration. The second series, Smithsonian Geographical Tables, appeared in 1894, editions slightly revised were issued in 1897 and 1906, and additional copies of the last edition were printed during the past year to meet the constant demand for this work. In 1896 there was published the Smithsonian Physical Tables, which have passed through several editions, the sixth revised edition being now in press. In this latest edition are incorporated many new tables and the insertion of recent data in the older tables to conform with the great advances in various fields of physical science. A fourth series is the Smithsonian Mathematical Tables (Hyperbolic Functions), published in 1909.

Smithsonian Report.—The distribution of the Annual Report for 1912 was long delayed, awaiting a supply of the quality of paper used in that publication. The volume contains 38 articles of the usual character in the general appendix. The report for 1913 was in type at the close of the fiscal year. The popularity of this publication continues unabated, the entire edition each year becoming exhausted very soon after its completion.

Special publications.—For several years past the Institution has issued in printed form the Opinions rendered by the International Commission on Zoölogical Nomenclature. During the past year Opinions 57 to 65 were thus published. To aid the work of this commission the Institution also provides for clerical services in connection with the office of its secretary in this country.

Another special publication of the year, printed in a limited edition, was a pamphlet giving an account of the exercises in the Smithsonian building on May 6, 1913, on the occasion of the presentation of the Langley medal to Monsieur Eiffel and to Mr. Glenn H. Curtiss, and the unveiling of the Langley memorial tablet.

Harriman Alaska Series.—In 1910 there was transferred to the Smithsonian Institution by Mrs. Edward H. Harriman the remainder of the edition of volumes 1 to 5 and 8 to 13 of the elaborate publication on the results of the Harriman Alaska Expedition of 1899. It may be recalled that this expedition was organized with the cooperation of the Washington Academy of Sciences, but entirely at the expense of the late Mr. Edward H. Harriman, of New York. It was participated in by a large party of scientific specialists, on a steamship specially chartered for the purpose. A narrative of the trip and observations on the regions visited, together with descriptions of the natural-history features of Alaska were prepared by specialists of the party and published in the series above mentioned. Volumes 6 and 7 on botany are still in preparation. During the past year volume 14 has been issued by the Smithsonian Institution. It is a monograph of the shallow-water starfishes of the North Pacific coast, from the Arctic Ocean to California, and is accompanied by 110 plates of illustrations.

National Museum publications.—The annual report for 1914 of the assistant secretary in charge of the National Museum was published during the year, together with 49 papers from the Museum Proceedings, and 9 Bulletins, including a number of parts of volumes of Contributions from the National Herbarium.

Ethnology publications.—The Bureau of American Ethnology issued during the year a bulletin on Chippewa Music and one on the Ethnozoology of the Tewa Indians. There were in press at the close of the year three annual reports and several bulletins, as noted in the second appendix of this report.

Astrophysical Observatory.—Volume 3 of the Annals of the Astrophysical Observatory was distributed early in the fiscal year.

Reports of historical and patriotic societies.—In accordance with the national charters of the American Historical Association and the National Society of the Daughters of the American Revolution, annual reports of those organizations were submitted to the Institution and communicated to Congress.

Allotments for printing.—The allotments to the Institution and its branches, under the head of "Public printing and binding," during the fiscal year, aggregating $76,200, were all utilized, with the exception of small balances on work in progress at the close of the year. The allotments for the year ending June 30, 1915, are as follows:

For the Smithsonian Institution: For printing and binding the annual reports of the Board of Regents, with general appendices	$10,000
For the annual reports of the National Museum, with general appendices, and for printing labels and blanks, and for the Bulletins and Proceedings of the National Museum, the editions of which shall not exceed 4,000 copies, and binding, in half morocco or material not more expensive, scientific books, and pamphlets presented to or acquired by the National Museum library	37,500
For the annual reports and Bulletins of the Bureau of American Ethnology and for miscellaneous printing and binding for the bureau	21,000
For miscellaneous printing and binding:	
International Exchanges	200
International Catalogue of Scientific Literature	100
National Zoological Park	200
Astrophysical Observatory	200
For the annual report of the American Historical Association	7,000
Total	76,200

Committee on printing and publication.—The advisory committee on printing and publication under the Smithsonian Institution has continued to examine manuscripts proposed for publication by the branches of the Institution and has considered various questions concerning public printing and binding. Twenty meetings of the committee were held during the year and 121 manuscripts were passed upon. The personnel of the committee during the year was as follows: Dr. Frederick W. True, Assistant Secretary of the Smithsonian Institution, chairman; Dr. C. G. Abbot, Director of the Astrophysical Observatory; Dr. Frank Baker, Superintendent of the National Zoological Park; Mr. A. Howard Clark, editor of the Smithsonian Institution, secretary of the committee; Mr. F. W. Hodge, Ethnologist-in-charge of the Bureau of American Ethnology; Dr. George P. Merrill, head curator of geology, United States National Museum; and Dr. Leonhard Stejneger, head curator of biology, United States National Museum.

Distribution of publications.—In accordance with the law enacted August 23, 1912, requiring that all Government publications be mailed from the Government Printing Office, the Smithsonian Report and publications of the United States National Museum and the Bureau of American Ethnology have since been distributed direct from the Government Printing Office.

LIBRARY.

The library of the Smithsonian Institution is its most valuable single possession. The number of publications of learned societies and of periodicals and other works pertaining to pure and applied science which have been brought together by the Institution since its organization aggregates more than half a million titles. In 1866 many of the scientific works in the library were transferred for various administrative reasons to the Library of Congress, where they form the Smithsonian deposit, which is constantly being increased by new accessions. The number of additions to the deposit during the past year was 32,195 pieces, including 20,603 periodicals, 3,765 volumes, 1,729 parts of volumes, 5,755 pamphlets, and 343 charts.

In the Smithsonian and Museum buildings there are retained such books of the Smithsonian Library as are needed for reference in scientific investigations, and there is maintained a reading room, where the current numbers of nearly 300 foreign and domestic scientific periodicals are on file for consultation by students in general and by the staff of the Institution and its branches.

In the main hall of the Smithsonian building steel stacks are being constructed for the better care and preservation of the libraries of the Government bureaus under the Institution.

Works on natural history, the arts and industries, and other subjects pertaining to the several departments of the National Museum are installed in the new and older Museum buildings. This library now numbers 43,609 volumes, 73,761 pamphlets and unbound papers, and 124 manuscripts.

In the assistant librarian's review of the year's operations in appendix 6 of this report details will be found as to the work of the library in its several subdivisions.

INTERNATIONAL CONGRESSES.

The Institution is frequently invited to send representatives to scientific congresses in the United States and abroad, but as funds are not available for the expenses of delegates, invitations can be accepted only in a few instances when collaborators of the Institution or members of the scientific staff are willing to attend at their own expense.

Your secretary, as a member of the Twelfth International Congress of Geology, would have attended the meeting in Toronto August 7 to 14, 1913, but he was unable to make arrangements to leave his field work in the Canadian Rockies at that time. He had an opportunity to address the members of the congress during their visit to Field, British Columbia. Dr. George P. Merrill, head curator of geology in the United States National Museum, however, attended the congress as representative of the Smithsonian Institution and the Museum.

Plans had been perfected at the close of the fiscal year for holding the Nineteenth International Congress of Americanists in Washington during the month of September, 1914.

GEORGE WASHINGTON MEMORIAL BUILDING.

In my last report reference was made to the act of Congress approved by the President March 4, 1913, authorizing the George Washington Memorial Association to erect a memorial building on Armory Square facing the Mall, which extends from the Capitol to the Washington Monument. The control and administration of the building, when erected, is in the Board of Regents of the Smithsonian Institution. Plans for the building were selected in May, 1914, from designs submitted by 13 competing architects, and were subsequently approved by the National Commission of Fine Arts.

The drawings depict a colonial building with pillared front and square ground plan. The main feature is an auditorium to seat 6,000 people, which is arranged in the form of an ellipse, with the stage at one end and a deep balcony encircling the whole.

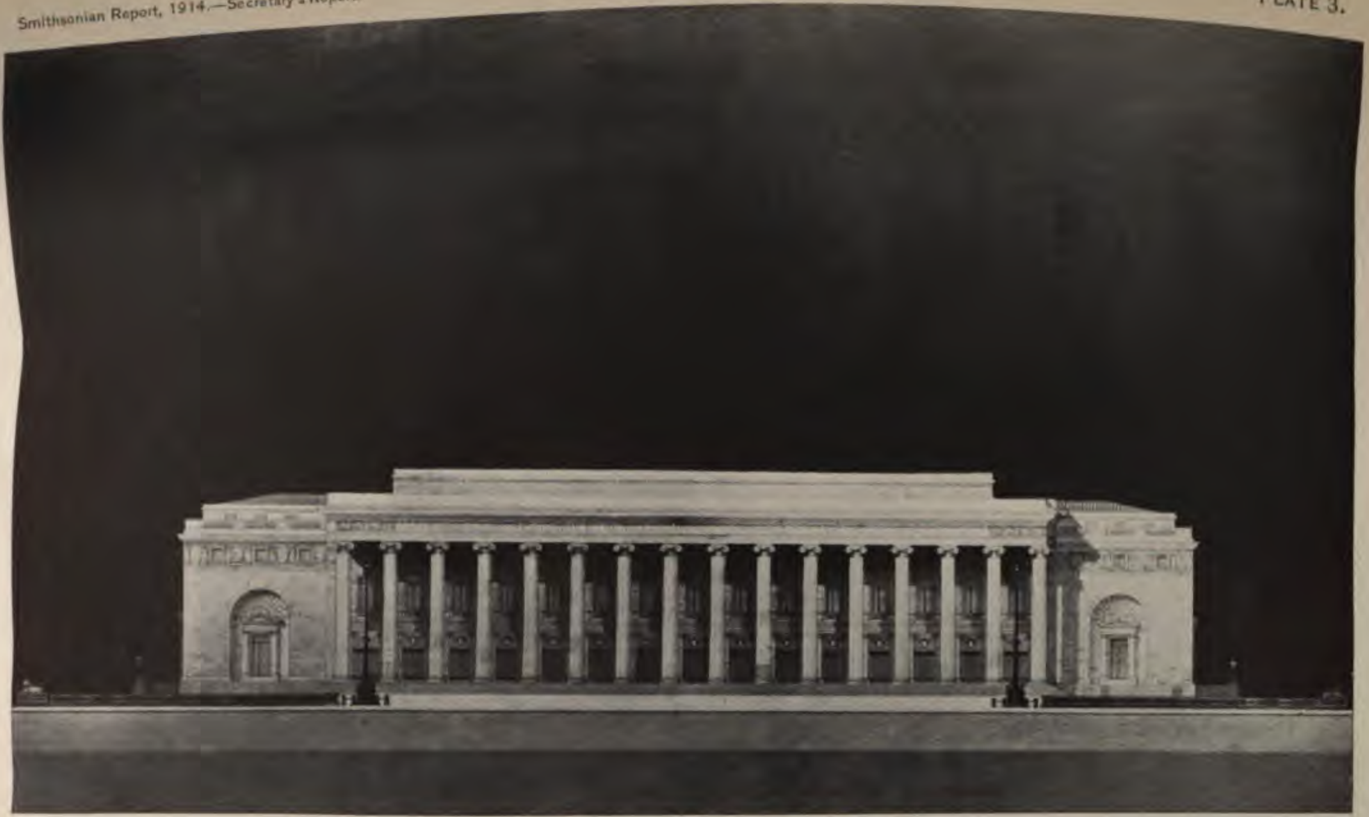
The work of construction must be begun before the 4th of March, 1915, or the authorization by Congress for the use of the above site will lapse. It is further provided that the work of construction can not be commenced until the sum of $1,000,000 is raised by the association, and although Mrs. Henry F. Dimock, president of the association and chairman of the building committee, has secured a part of this sum, much still remains to be raised.

The cost of the building must be not less than $2,000,000, and there must be provided for its maintenance a permanent fund of not less than $500,000. In the preamble of the original bill (S. 5494) passed by the Senate April 15, 1912, "to provide a site for the erection of a building to be known as the George Washington Memorial Building, to serve as the gathering place and headquarters of patriotic, scientific, medical, and other organizations interested in promoting the welfare of the American people," the purpose of the building is defined as follows:

> Whereas George Washington, on July 9, 1799, said, "It has been my ardent wish to see a plan devised on a liberal scale which would spread systematic ideas through all parts of this rising empire," and it was Washington's wish to materially assist in the development of his beloved country through the promotion of science, literature, and art, and with the firm conviction that "knowledge is the surest basis of public happiness"; and
>
> Whereas the changing conditions that time has brought require new methods of accomplishing the results desired by Washington and now a necessity of the American people; and
>
> Whereas at the present time there is not any suitable building in the city of Washington where large conventions or in which large public functions can be held, or where the permanent headquarters and records of national organizations can be administered; and
>
> Whereas a building should be provided in which there shall be a large auditorium, halls of different sizes where all societies pertaining to the growth of our best interests can meet, and such as it is deemed desirable may have permanent headquarters; and
>
> Whereas the George Washington Memorial Association is now engaged in obtaining funds for the erection and endowment of a building suitable for the purposes above set forth, to be known as the George Washington Memorial Building: Therefore * * *

The law as passed by Congress and approved by the President March 4, 1913, was as follows:

> *Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled:*
>
> * * * * * * *
>
> SEC. 10. That a building is hereby authorized to be erected in the District of Columbia, to be known as the George Washington Memorial Building.
>
> The control and administration of said building, when erected, shall be in the Board of Regents of the Smithsonian Institution.
>
> The George Washington Memorial Association is authorized to erect said building in accordance with plans to be procured by said association and to be approved by the Commission of Fine Arts, said building to be fireproof, faced with granite, and to cost not less than $2,000,000; it shall have an auditorium that will seat not less than six thousand people, and such other smaller halls, reception rooms, office rooms, and so forth, as may be deemed necessary to



APPROVED DESIGN FOR GEORGE WASHINGTON MEMORIAL BUILDING.

carry out the purposes for which the building is erected. And the said George Washington Memorial Association shall in addition provide a permanent endowment fund of not less than $500,000, to be administered by the Board of Regents of the Smithsonian Institution, the income from which shall, as far as necessary, be used for the maintenance of the said building.

Permission is granted the George Washington Memorial Association to erect said building in the north end of the reservation known as Armory Square, bounded by Sixth and Seventh Streets west and B Street north and B Street south. The south front of said building is to be on a line with the south front of the new National Museum Building, in the north end of the Smithsonian Park; and the said land is hereby set apart for that purpose: *Provided*, That the actual construction of said building shall not be undertaken until the sum of $1,000,000 shall have been subscribed and paid into the treasury of the George Washington Memorial Association: *And provided further*, That the erection of said George Washington Memorial Building be begun within a period of two years from and after the passage of this act, and this section shall be null and void should the George Washington Memorial Association fail to comply with the provisions thereof, which are conditions precedent to the authorization herein granted.

Said building may, among other purposes, be used for inaugural receptions and special public meetings authorized by Congress.

Congress may alter, amend, add to, or repeal any of the provisions of this section.

NATIONAL MUSEUM.

Since the operations of the Museum are reviewed by Assistant Secretary Rathbun in the first appendix of this report and are discussed in detail in a separate volume, it seems unnecessary for me here to do more than to allude to some of the more important features of the year's work. The growth of the Museum during recent years has been greater than during any prior period of its history. Confined as it was for more than 30 years within restricted quarters poorly adapted for many classes of exhibits, its growth was greatly hindered and its value to the public hampered in many ways. With the completion of the new building, however, there has come an era of greater usefulness to the Nation in every direction. The natural history collections are now given adequate room in the spacious halls of the new building, while in the older structure opportunity is afforded for the proper display of objects relating to the arts and industries and to American history. Increase in every division of the three principal departments of the Museum—anthropology, biology, and geology—is now welcomed both for purposes of exhibition and in the study series.

During the last fiscal year there was added a total of 337,705 objects, 14,879 of which pertained to anthropology, 257,816 to zoology, 44,675 to botany, 3,648 to geology and mineralogy, 13,045 to paleontology, 2,930 to textiles and other animal and vegetable products, 505 to mineral technology, and 207 to the National Gallery of Art. The relative importance of many classes of objects thus acquired is referred to in the assistant secretary's report. Among the most noteworthy accessions in ethnology were more than 500 objects from Dutch New Guinea, the Moluccas and Ambon of the Ceram group, collected and presented by Dr. W. L. Abbott, who has done so much for the Museum in past years toward increasing our knowledge of the zoology and ethnology of the Far East. Among the important acquisitions in biology were some 200,000 insects obtained by entomologists of the Department of Agriculture during economic investigations; a generous donation from Dr. E. A. Mearns, consisting of his large private collection of bird skins, eggs, and skeletons, containing many rarities; and over 10,000 specimens, mainly grasses, from the Department of Agriculture. Additions in geology and mineralogy included a 200-pound specimen of copper from Nevada; many specimens of minerals from various sources, including rare and excellent examples and some new forms; meteorites; Cambrian fossils; and three valuable type collections pertaining to the paleobotany of Alaska and other regions. Dr. E. O. Ulrich presented about 3,000 Paleozoic fossils of much value to the Museum. The division of textiles has been enriched by many important accessions and has been much extended in its scope during the year.

In the division of history there were large additions to memorials of eminent Americans and of historic events. An exhibit of period costumes installed in one of the history halls has attracted much attention. It includes a series of costumes worn by wives of many of the Presidents of the United States, and contains valuable examples of the styles of dress in America since the colonial period and a variety of articles of domestic and personal use. A unique photographic exhibit illustrates the apparatus and results of all stages of that art since the first attempts to obtain pictures through the agency of the sun.

The collection of fine arts has been enriched by further gifts from Mr. Charles L. Freer, of Detroit. His original gift, made in 1906, contained about 2,300 objects, and has since been increased to 4,701 most interesting and valuable examples of oriental and American art. The collection remains in the possession of the donor during his life. Mr. Freer has provided for the construction of a suitable building adjacent to the National Museum for the permanent preservation and display of the collection. Among permanent additions to the National Gallery were a number of paintings. The loans aggregated 109 paintings and 3 pieces of sculpture from various sources.

I have elsewhere mentioned the bequest to the Institution by Dr. Chamberlain of $35,000, establishing a fund to promote the increase and scientific value of the Isaac Lea collections of precious stones and fresh-water mussels in the Museum.

In the interest of general education, particularly in natural history, it has been the custom for many years to distribute to schools and colleges throughout the country such duplicate material as can be spared from the Museum collections. During the past year 14,564 specimens were thus distributed, besides several hundred pounds of rocks, minerals, and ores.

The total attendance of visitors to the new or natural history building during the year was 267,728 for week days and 61,653 on Sundays, while the older building was visited by 146,533 persons.

The publications of the year numbered 14 volumes and 58 separate papers. The library has now increased to a total of 43,609 volumes and 73,765 pamphlets and other unbound papers.

The auditorium and other available rooms in the new building have proved of great convenience for meetings of scientific bodies and were largely utilized during the year. Accommodations were also afforded for several conventions of agriculturists, accompanied by exhibits of wool, fruits, and other products

BUREAU OF AMERICAN ETHNOLOGY.

The work of the Bureau of American Ethnology during the year has brought together much new material relating to the habits and customs and the languages of the American Indians. The results of the studies of the several investigators are being published as promptly as practicable. The systematic researches by the ethnologists forming the scientific staff of the bureau are described in detail in the second appendix of this report. I may mention as of special interest a reconnoissance by Mr. F. W. Hodge, Ethnologist-in-charge, of a group of prehistoric ruins on a mesa in Cebollita Valley, N. Mex. These ruins consist of a number of house groups forming a compound built on an almost impregnable height, and designed for defense; not only the groups but the individual houses have the form of fortifications, while the vulnerable point of the mesa rim is protected by means of a rude breastwork of stones. The outer wall, which protects the whole mesa, is built of exceptionally fine masonry, probably the finest work to be found in ancient pueblo ruins of the Southwest. The building stones have been dressed to shape, matched for size, and their faces finished by pecking, with such labor as to confirm the belief that this ancient village was designed for permanent occupancy. Among the special features of interest which Mr. Hodge discovered were a burial cist in which skeletons, pottery, and the remains of a mat were found; three small cliff lodges situated in the sides of the cliffs; several ceremonial rooms or kivas associated with the ruined houses; and the remains of the early reservoirs of the inhabitants.

A study was made by Dr. Fewkes of prehistoric antiquities in the Lesser Antilles and material gathered for a proposed monograph on the aborigines of those islands. Examination was made of many village sites, prehistoric mounds, shell heaps, and bowlders bearing incised pictographs. In a shell heap in Trinidad there was found a valuable collection of animal heads made of terra cotta and stone and other implements illustrating the early culture of the island. As a result of his researches thus far, Dr. Fewkes concludes that—

> The New World, when discovered, had not advanced in autochthonous development beyond the neolithic age, whereas in Asia, Europe, and Africa a neolithic age was supplemented by one in which metals had replaced stone for implements. In the Old World this polished-stone epoch was preceded by a paleolithic stone age not represented, so far as is known, in America. The ethnology and archeology of our Indians is therefore only a chapter, and that a brief one, of a segment of a much more extended racial evolution, as illustrated in Asia, Europe, and Africa.

Further study was made by Mr. Mooney of the sacred formulas of the Cherokee Indians in North Carolina. In connection with this work a collection of medicinal plants was made, including some specimens of the native corn still cultivated as sacred and found to be a new and hitherto undescribed variety of special food importance under cultivation.

Investigations also progressed among the Fox Indians, the Creeks, Osage, Seneca, and other tribes, and in the study of various Indian languages and ceremonies much advancement was made. Toward a work on the habits and customs and ceremonies of the Tewa Indians of New Mexico there has been brought together much interesting information.

Several years ago there was begun a series of handbooks on the American Indians. The first of these was issued in two volumes, entitled "Handbook of American Indians North of Mexico," and contains a descriptive list of the stocks, confederacies, tribes, tribal divisions, and settlements north of Mexico, with sketches of their history, archeology, manners, arts, customs, and institutions. The work proved of so great value to the public that several reprintings became necessary, including a special reprint by the Canadian Government.

The Handbook of American Indian Languages forms the second of the series. Part I of this handbook has been published and portions of the second part have been printed in separate form. This work discusses the characteristics and classification of the languages of the American Indians and their relation to ethnology. In North America north of Mexico there are distinguished 55 linguistic families. The first volume of the handbook contains sketches of a number of the languages of the northern portion of the continent, in-solar radiation, its variability from day to day, and the effect of the atmospheric water vapor in absorbing the radiations of great wave length such as are emitted toward space by the earth. Much attention has been given to the design, construction, and testing of new apparatus for these researches, including apparatus for measuring the sky radiation, special recording pyrheliometers to be attached to free balloons for the purpose of measuring solar radiation at great altitudes, and a tower telescope at the Mount Wilson Station.

The principal results of the year include: A new determination of the number of molecules per cubic centimeter of gas, depending on measurements at Mount Wilson of the transparency of the atmosphere; successful measurements by balloon pyrheliometers of the intensity of solar radiation up to nearly 45,000 feet elevation above sea level. The results tend to confirm the adopted value of the solar constant of radiation. Most important of all, the investigation by the tower telescope at Mount Wilson shows that the distribution of radiation along the diameter of the sun's disk varies from day to day and from year to year. These variations are closely correlated with the variations of the total amount of the sun's radiation. Thus the work of the year yields an independent proof of the variability of the sun and tends to elucidate its nature.

INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE.

The United States Bureau of the International Catalogue is administered by the Smithsonian Institution through a small annual appropriation by Congress. It is one of 33 regional bureaus in various countries engaged in the collecting, indexing, and classifying of scientific publications of the year, and the classified references are forwarded to the central bureau in London, where they are collated and published in a series of 17 annual volumes covering each branch of science and aggregating about 8,000 printed pages. These volumes are sold at an annual subscription price of $85, chiefly to large reference libraries and important scientific institutions, the proceeds covering in part the cost of publication. During the past year there was forwarded to London from the United States bureau a total of 28,606 reference cards, making a total of 318,936 cards prepared in the United States since the system was organized in 1901.

NECROLOGY.

Augustus Octavius Bacon was born in Bryan County, Ga., October 20, 1839, and died in Washington City February 14, 1914. He became a member of the Board of Regents in 1905 and for three years had served on the executive committee. Mr. Bacon was educated at the University of Georgia in 1859 and was honored with the degree of doctor of laws in 1909. He was for many years engaged in law practice at Macon, Ga. He became a United States Senator on March 4, 1895, and was thrice reelected, serving on many important committees of that body. As a Regent of the Smithsonian Institution he took deep interest in the development of plans for the advancement of science and the general welfare of mankind.

Irvin St. Clare Pepper, born in Davis County, Iowa, June 10, 1876, became a member of the Board of Regents of the Smithsonian Institution in December, 1911, and was reappointed December 10, 1913. He died on December 22, 1913. Mr. Pepper graduated from the Southern Iowa Normal School in 1897 and received the degree of bachelor of laws from the George Washington University in 1905, and in 1906 entered law practice at Muscatine, Iowa. He was county attorney from 1906 to 1910 and member of the Sixty-second and Sixty-third Congresses. Resolutions to the memory of Mr. Pepper were adopted by the Regents at the adjourned annual meeting January 15, 1914.

Frederick William True, born at Middletown, Conn., July 8, 1858, died in Washington City June 25, 1914. He was appointed an Assistant Secretary of the Smithsonian Institution June 1, 1911, his special duties being in connection with the library and international exchanges. Dr. True had held various positions of trust under the Institution since 1881. The following tribute to his memory was adopted by his associates at a meeting on June 26, 1914:

> Frederick William True, master of science, doctor of laws, Assistant Secretary of the Smithsonian Institution, died at Washington, D. C., June 25, 1914, in the fifty-sixth year of his age.
>
> His associates in the Smithsonian Institution and its several branches, assembled at a meeting in his memory at the United States National Museum on June 26, do here record their profound sorrow in the loss of an honored scholar, an executive officer of marked ability, a sincere friend, a patriotic citizen, and a modest man.
>
> Graduated from the New York University at the early age of 20, he at once entered the service of the United States as the youngest member of the scientific corps brought together by Profs. G. Brown Goode and Spencer F. Baird during the formative stages of the National Museum. Through faithful performance of duty in positions of trust he leaves to his associates an example worthy of emulation, and through his unassuming and upright personality a cherished memory.

Respectfully submitted.

CHARLES D. WALCOTT, *Secretary.*

APPENDIX 1.

REPORT ON THE UNITED STATES NATIONAL MUSEUM.

SIR: I have the honor to submit the following report on the operations of the United States National Museum for the fiscal year ending June 30, 1914:

INTRODUCTORY.

The last report contains a brief review of the exhibits in the new building, which mainly relate to zoölogy, geology, and anthropology, though also including the paintings of the National Gallery of Art and certain special and temporary installations. The natural history collections, while presenting a generally finished appearance, are, however, as there explained, still incomplete and to a large extent provisional in their arrangement. Considerable progress toward their improvement was made during last year, and this work will be continued as rapidly as possible until, to the extent of the material available, some degree of perfection has been reached, but the purposes of the Museum would be poorly served if more or less, and even radical, changes were not made from time to time in those parts of the collections which belong especially to the public.

Because of extensive interior alterations going on in the Smithsonian building, it was necessary temporarily to withdraw the graphic arts collection from display, but upon the completion of this work the surroundings for this important division will be greatly improved. In the older Museum building, moreover, there was much activity in connection with the exhibits, though not as much was accomplished as was desirable or would have been possible with a slightly increased appropriation. This building has been entirely given over to the arts and industries and American history. Square in shape, its exhibition space, amounting to about 100,000 square feet, is divided into four naves or halls, radiating from a central pavilion, the naves in turn being connected by ranges, eight in number, which follow the outer walls of the building and inclose four square covered courts. Although consisting of only a single story, except in the towers and pavilions, which are used for offices, most of the halls are supplemented by galleries. The building faces north, and its different subdivisions are designated by their position with reference to the rotunda. In planning for the distribution of the collections it has not been found possible to provide for all of the subjects which should be comprehended, and the fact that a few of the halls are still unarranged is due in part to the insufficient force and in part to the length of time required for the preparation of many of the exhibits. A brief summary of the conditions at the close of the year may, however, be of some interest.

The division of history, formerly limited to the north hall, has been extended into the west north range and the north west range, and also occupies the floor space in the northwest court. The hall and connecting range contain the general collection of history, consisting chiefly of memorials. The collection of musical instruments previously filling the large wall cases along the sides of this hall, though not belonging to this division, have been removed to a corresponding position in the northwest court, leaving these cases to be used for historical furniture, of which the Museum has many important pieces. In one of them, however, "The Star-Spangled Banner" still remains, pending arrangements for a better installation. In the north west range has been placed the period costume collection, which was first opened to the public in February last. This noteworthy feature, which centers upon a series of White House costumes draped on manikins, contains many and valuable examples of the styles of dress in America from the colonial period to the present time, besides a great variety of articles of domestic and personal use. In the adjoining or northwest court are the coins and medals and the postage stamps, also an installation of last year. The former are shown in table cases, but the stamps required a special arrangement which has been carried out in the form of two long upright cases, fitted with framed sliding screens to which the stamps are attached. The gallery of this court is devoted to the unique photographic exhibit, illustrating by apparatus and results all of the stages in the progress of this art from the first attempts at obtaining pictures through the agency of the sun. The opening of this display was likewise a feature of the year.

On the left-hand side of the building on entering is the art textile collection in the east north range, followed by the boat hall, or north east range, in both of which but few changes were made. The division of mechanical technology, to which the exhibit of boats belongs, also occupies the east hall, the northeast court, and about one-half of the south east range. The court is mainly given over to small arms, both military and other, of which the collection is the largest and most varied in this country. The remaining space is used for a considerable variety of subjects, such as land and air transportation, electricity in its several applications, measures of space and time, and many miscellaneous devices and inventions, which are well displayed and labeled and to which numerous additions have recently been made. In the gallery of the court are the collections of ceramics, glassware, bronzes, etc., and in the north gallery of the hall is the exhibit of the division of medicine.

The southern part of the building has been allotted to two divisions, which, organized some 30 years ago but soon discontinued on account of lack of space, have recently been reestablished on a broader basis and have already attained considerable prominence. One of these is the division of textiles, including also such animal and vegetable products as do not specifically belong elsewhere. To this division have been assigned the south hall, the east south range, and the southeast court, together with a considerable amount of gallery space. While much of the original collection, when removed from storage, was found to be still serviceable, the greater part of the textile display, which is exceedingly rich and varied in its representation of this industry in the United States, is the accumulation of only two years. There is also a fair illustration of the work done in the Philippines and some examples from Porto Rico. The exhibition of animal and vegetable products is much less advanced, and there is still to be taken up the subjects of commercial woods and of foods.

The division of mechanical technology has been assigned the west hall, the southwest and west south ranges, and the southwest court. the occupation of all of which has been planned, in part definitely, in part provisionally. The objects of this division are to illustrate the processes involved in extracting minerals from the earth, and in the utilization of the products so obtained, with the intention of covering all the important minerals, both metallic and nonmetallic. Progress with this exhibition will be slow, because of the time required to build models, in which the mining and manufacturing interests are giving hearty and generous support, even to the extent of furnishing expensive reproductions of their works and operations. The first of the exhibits, opened to the public last year, relate mainly to the subject of coal, and include several excellent models, the largest of which, representing a bituminous colliery, occupies fully half the floor space of the southwest court. A number of other models and exhibits were also completed and installed, and additional ones were in course of construction.

COLLECTIONS.

The additions to the collections aggregated approximately 337,705 specimens, apportioned among the several branches of the Museum as follows, namely: Anthropology, 14,879; zoology, 257,816, of which over 214,000 were insects; botany, 44,675; geology and mineralogy, 3,648; paleontology, 13,045; textiles and other animal and vegetable products, 2,930; mineral technology, 505; and the National Gallery of Art, 207. There were also received as loans 2,280 objects, mainly for the exhibition series in ethnology, archeology, history, and the Gallery of Art.

The most noteworthy accessions in ethnology consisted of over 500 objects from northern Dutch New Guinea, the Moluccas and Ambon of the Ceram group, collected and presented by Dr. W. L. Abbott; an especially important lot of material obtained at St. Lawrence Island, Alaska, by Dr. Riley D. Moore, of the Museum staff; and a series of Siouan ethnologica of particular value, as the locality and tribal origin of the specimens are properly recorded. The principal additions in American archeology comprised material from old Indian camp sites and caves in Patagonia and from Guatemala, the results of explorations by Mr. Chester W. Washburne in the former region, and by Mr. Neil M. Judd in the latter; an interesting series of stone implements from Jackson County, Mo., presented by Mr. J. G. Braecklein; and a large number of exceptionally fine specimens of the same character from Missouri and Illinois, purchased from Mr. D. I. Bushnell, jr. The collection of Old World archeology was enriched by a drawing in color of an ancient mosaic map of Palestine and adjacent regions, the gift of Mr. S. W. Woodward; an important contribution from the Egypt Exploration Fund through Mr. Woodward; a large number of ancient coins and other objects from the Near East, lent by Mrs. John Paul Tyler; and several series of prehistoric material from Europe. The more notable accessions in physical anthropology consisted of human crania and skeletons, mainly of the Eskimo and Aleuts, the Buriats of central Siberia, the Mongolians, the natives of Mělnik, Bohemia, the Patagonians, and early man in Europe. The division of mechanical technology received a circular sundial adapted to the latitude of Peking and inscribed in Chinese characters from Mr. Claude L. Woolley; a set of ancient German coin scales made by Johann Daniel Ellinghaus, in Radevormwalde, Germany; important additions to the series of firearms, and many other objects. There were a number of interesting contributions in pottery and bronze, and also several desirable gifts to the collections of graphic arts and musical instruments.

The division of history was the recipient of many accessions, some of which were of much value, and an exceptionally large percentage were permanent acquisitions. There were additions to the Washington collection; pieces of furniture formerly belonging to Alexander Hamilton and Gen. Philip Schuyler; relics of Rear Admiral Charles Wilkes, United States Navy; of Aaron Burr, and of Prof. Spencer F. Baird; the sword carried by Brig. Gen. Strong Vincent, United States Volunteers, when mortally wounded at Little Round Top, Gettysburg; and a large collection of canes, interesting historically as well as for their workmanship, some having been owned by persons of high distinction. The collection of postage stamps, postal cards, and stamped envelopes was increased to the extent of about 9,000 examples, and many additions were made to the series of coins and medals and of portrait photographs. So many contributions were received for the period costume collection as to permit of the installation and opening of the hall allotted to this subject.

Especially notable among the acquisitions in biology were some 200,000 insects obtained by entomologists of the Department of Agriculture during economic investigations in Texas and neighboring States. Mr. H. C. Raven, whose work has continued to be maintained by Dr. W. L. Abbott, sent over 1,500 mammals and birds from eastern Borneo, including numerous rare and probably some new forms. Besides extensive collections of fishes and marine invertebrates, the Bureau of Fisheries transferred a large number of reptiles and batrachians from various parts of North America, and the first series, with the types, of the mammals obtained in Lower California during the cruise of the steamer *Albatross* in 1911. The Biological Survey, in addition to its regular deposits of North American mammals and birds, turned over to the Museum many mammals from Patagonia and reptiles and batrachians from Panama, and Prof. A. M. Reese contributed a large quantity of specimens of several groups collected by him at the Philippine Islands. Additional mammals were received from China, Africa, the island of Sardinia, etc., and reptiles and batrachians from California, Mississippi, Alabama, and other southern States. A generous donation from Dr. E. A. Mearns, United States Army, retired, consisted of his large private collection of bird skins, eggs, and skeletons, containing many rarities. Other sources of fishes than those above referred to were Japan, Fanning Island, the Philippines, Panama, and California; and of insects, the Bahama Islands, Florida, the southwestern and western States, and Alaska, besides which important series in several groups of insects of economic importance were among the contributions. The division of mollusks received as gifts the important collection of the late Prof. F. W. Bryant, of Lakeside, Cal.; about 2,000 specimens obtained by Mr. John B. Henderson, jr., during a dredging expedition to the vicinity of Chincoteague, Va., and many other valuable donations. The marine invertebrates from the Bureau of Fisheries consisted chiefly of material in several groups which had been the subject of study and report. About 100 species of rotifers, mounted on slides, were presented by Mr. H. K. Harring, and numerous more or less important collections were received from various sources. The additions to the herbarium comprised over 10,000 specimens, mainly of grasses, from the Department of Agriculture, resulting from recent field work; about 3,500 West Indian and African plants from the New

York Botanical Garden; nearly 1,600 Chinese plants from the collection of Mr. E. H. Wilson; about 10,000 specimens of cryptogams collected by the late John B. Leiberg and presented by Mrs. Leiberg; and important contributions from Venezuela, Guam, the Philippines, and the southern and southwestern States.

Among the additions in geology and mineralogy were an important series of rocks and ores from the Sudbury nickel region and the Cobalt mining district of Canada; a suite of recently described minerals from Peru; a 200-pound specimen of copper from Nevada; an unusual deposit of carnotite in a fossil tree trunk; a large piece of quartz vein, containing an abundant development of blade-like crystals of tungsten ore; and many specimens of minerals from various sources, including rare and excellent examples and some new forms. The collections of meteorites and building stones received many desirable additions, and the Geological Survey deposited a number of series of rocks, of petrological value, from different parts of this country and from Hawaii. The accessions in invertebrate paleontology included about 150 types of Cambrian fossils collected and described by Secretary Walcott; some 5,000 specimens from the Middle Cambrian of British Columbia, also collected by him; and about 150 type specimens of Bryozoa and Ostracoda, representing work of the curator of the division on the Silurian collections from the island of Anticosti, preserved at Yale University. The Geological Survey transferred several collections, some of which had been described; Dr. E. O. Ulrich presented about 3,000 Paleozoic fossils, of much value to the Museum; and an important series of Tertiary mollusks and Ordovician graptolites was received in exchange from Australia. The most important acquisitions in vertebrate paleontology consisted of a large collection made by Mr. Charles W. Gilmore in the Blackfeet Indian Reservation; of the results of further explorations by Mr. James W. Gidley in the Pleistocene cave deposits near Cumberland, Md.; and of cetacean remains collected in the Miocene beds near Chesapeake Beach, Md., by Mr. William Palmer and Mr. Norman H. Boss. The section of paleobotany was enriched by three valuable type collections from the Geological Survey, representing the Jurassic formation at Cape Lisburne, Alaska; the Tuscaloosa formation of Alabama; and the Cretaceous and Tertiary in South Carolina and Georgia.

The number and value of the accessions in the division of textiles were greatly increased over those of the previous year, due to the appreciation shown by the producers in the important work which the Museum has undertaken. Only a brief summary can here be given of the many contributions which were almost wholly in the form of gifts. To the cotton collection were added fancy wash dress goods and shirtings, comprising pleasing and artistic combinations of plain, ratine, and mercerized cotton yarns, with spun silk and viscose silk in plain and fancy weaves; plain, piece-dyed and yarn-dyed dress goods of all cotton and cotton and artificial silk; cotton fabrics finished to imitate those of silk and of wool and fancy printed cotton velvets in gold and silver effects for millinery purposes. The collection of wool and woolen products was enriched by a large assortment of new fleeces of the best American and foreign wools, all carefully graded and labeled to show the value in the grease and when scoured; specimens marking the steps in the manufacture of both woolen and worsted goods, and many pieces of finished fabrics of both classes. The already extensive silk collection was enlarged by the addition of a commercial package of skeins of the finest Japanese raw silk, many yards of printed broad silks representing the latest seasonable designs, brocaded novelty silks for dress trimmings, and samples of ties, scarfs, veilings, and ribbons of all kinds. Another important acquisition was the oldest model of the Grant silk reel, now in universal use for winding silk into standardized crossed skeins. The manufacture of fur felt hats from the finest grades of beaver, nutria, hare, and coney furs was illustrated by a comprehensive collection showing each step in the process from the fur pelt to the finished hat, and including the leather and silk trimmings for the principal types of hats. The development of an artist's plan for the decoration of a fabric by weaving or printing was represented by a series of preliminary sketches, weaver's drafts, and engraved plates for use on the pantograph machine, all bearing on the technology of design.

In the division of mineral technology, including a few of the exhibits presented at the St. Louis exposition of 1904, which had not previously been unpacked and recorded, the principal accessions of the year were as follows: A very full illustration of the processes of glass making; a complete working model of a bituminous colliery at Fairmont, W. Va., covering a space of 30 by 40 feet; a reproduction of a bituminous mine at Willock, Pa., 8 by 12 feet square, which excellently supplements the former; a relief panel illustrating processes involved in the manufacture of illuminating gas, tar, ammonia, and other coal products in what is known as the by-products coke industry; a number of photographic enlargements depicting typical underground operations incidental to coal mining; a series of native gypsum and gypsum products; and a collection illustrating crude mica and its industrial products.

NATIONAL GALLERY OF ART.

The most important acquisition consisted of the formal transfer to the Institution, by Mr. Charles L. Freer, of Detroit, Mich., of 198 objects as additions to his munificent gift to the Nation, comprising the material which he had assembled since the last previous transfer in November, 1912. This collection, as will be recalled, relates wholly to American and oriental art, and is to remain in the possession of the donor during his life. The original gift, made in 1906, contained approximately 2,326 objects, but through subsequent contributions this number has been increased to 4,701, of which 983 are examples of American art and 3,718 are examples of oriental art. These may be summarized as follows:

In the American section James McNeill Whistler is represented by 62 oil paintings, 44 water colors, 32 pastels, and 798 drawings, etchings, lithographs, etc., besides 1 album of sketches, 38 original copper plates, and the entire decoration of the famous Peacock Room. The remainder of this section is composed of 75 oil paintings, 6 water colors, 25 pastels, and 1 silver point, illustrating the work of 9 other American painters, namely, Thomas Wilmer Dewing, Childe Hassam, Winslow Homer, J. Gari Melchers, John Singer Sargent, Joseph Lindon Smith, Abbott Handerson Thayer, Dwight William Tryon, and John Henry Twachtman. The oriental paintings comprise 826 screens, panels, kakemono, and makimono from Japan and China; 32 albums of paintings and sketches from the same countries; and 13 paintings from Tibet. Of oriental pottery there are 1,665 pieces, mainly from Japan, China, Corea, central and western Asia, and Egypt; of bronzes, 236 pieces, of which over 200 came from China; of stone objects, including sculptures, 234 pieces, mainly Chinese; of wood carvings, 17 pieces; and of lacquered objects, 31 pieces. The collection also contains over 600 pieces of ancient Egyptian glass in the form of bottles, vases, and various other shapes, besides a large number of miscellaneous objects from both the Far and Near East.

Other permanent additions to the Gallery consisted of 3 paintings by Miss Clara Taggart MacChesney, Guy C. Wiggins, and Addison T. Millar, respectively, contributed by Mr. William T. Evans, of New York; a painting by Du Bois Fenelon Hasbrouck, presented by Mr. Frederic Fairchild Sherman in memory of his wife; and 4 paintings by Walter Shirlaw and a portrait sketch of him by Frank Duveneck, received as a gift from Mrs. Shirlaw.

The loans to the Gallery aggregated 109 paintings and 3 pieces of sculpture from 12 sources. Eighty-one of the paintings were received for 2 special exhibitions, the first comprising 25 portraits in oil from the National Association of Portrait Painters, the other consisting of 56 marine paintings by Mr. William F. Halsall, of Boston.

MISCELLANEOUS.

It is gratifying to announce a bequest by the late Rev. Dr. Leander Trowbridge Chamberlain, an honorary associate of the Museum. of the sum of $35,000, to be known as the Frances Lea Chamberlain fund, the income of which is to be used for promoting the increase and the scientific value and usefulness of the two important Isaac Lea collections, $25,000 being given on account of the gems and precious stones and $10,000 on account of the fresh-water mussels or Unionidæ. Owing to delay in the settlement of the will, payment had not been made to the Institution at the close of the year.

By the will of Miss Lucy Hunter Baird, daughter of Prof. Spencer F. Baird, the second Secretary of the Smithsonian Institution, the Museum received during the year many interesting objects for its collections and several hundred important books for its library.

The distribution of duplicate material suitable for teaching purposes to schools and colleges in all parts of the country aggregated 14,564 specimens, besides several hundred pounds of rock and mineral fragments for blowpipe analysis. These were sent out in 148 separate sets, and consisted mainly of rocks, minerals, ores, fossils, and mollusks and other marine invertebrates. In exchange transactions with other establishments and with individuals over 15,000 duplicates were used, about 80 per cent of this number being plants. The loans to specialists for study comprised 10,256 specimens of animals and plants, and 5,425 specimens from the department of geology, besides 746 unassorted lots of marine invertebrates and 107 lots of fossils.

The total attendance of visitors at the new building aggregated 267,728 for week days and 61,653 for Sundays, making the daily average for the former 855 and for the latter 1,185. The number who visited the older Museum building was 146,533, a daily average of 486, and the Smithsonian building 102,645, a daily average of 328. The falling off in attendance at these two buildings may be ascribed to the fact that many of the halls in the former, emptied by the withdrawal of the natural history collections, have not yet received their new installations, and extensive rearrangements and repairs in the Smithsonian building practically caused the closing of its exhibition rooms for a considerable part of the year.

The publications of the year numbered 14 volumes and 58 separate papers, 49 of the latter belonging to the series of Proceedings and 9 to the Contributions from the National Herbarium. In addition, 31 short papers on materials in the collections of the Museum, relating mainly to new discoveries, were printed in the Smithsonian Miscellaneous Collections. The total distribution of Museum publications amounted to about 93,200 copies.

The library received 1,917 volumes, 1,723 pamphlets, and 132 parts of volumes, and its total contents were thereby increased to 43,609 volumes and 73,765 pamphlets and other unbound papers, the greater part of which have been obtained through exchange and as gifts. Good progress was made in the reorganization and arrangement of the section of the library relating to the arts and industries, which occupies the former library quarters in the older Museum building.

The auditorium and other rooms in the new building were frequently used for meetings and public gatherings having objects akin to those of the Institution, and also by several bureaus of the Government for official purposes. The regular meetings of the Washington Society of the Fine Arts and the Anthropological Society of Washington were held here, as were the public sessions of the annual meeting of the National Academy of Sciences and the meetings of the Spanish-American Atheneum and the American Ornithologists' Union. Lectures were delivered under the auspices of the Washington Academy of Sciences, the Medical Society of the District of Columbia, the Washington Society of Engineers, the George Washington University, the Washington Society of the Archæological Institute of America, the Germanistic Society of Washington, the Columbia Chapter of the Daughters of the American Revolution, the District of Columbia Chapter of the Guild of American Organists and other musical societies, and the Home Club of the Department of the Interior. A special program of American music was also rendered by the Friday Morning Music Club. Of three congresses, one held in Chicago, the others in Washington, each had a special meeting in the auditorium for addresses by distinguished persons. These were the Third International Congress of Refrigeration, the fourth annual meeting of the American Association for Study and Prevention of Infant Mortality, and the Third International Congress on the Welfare of the Child. On April 18, 1914, a reception to the Daughters of the American Revolution was given by the Secretary of the Institution.

The accommodations afforded by the new building were utilized on numerous occasions by bureaus of the Department of Agriculture for meetings, conferences, and hearings, including a series of lectures under the Bureau of Plant Industry and a conference with the woolgrowers, accompanied by an excellent exhibition of wool specimens, which has been deposited in the Museum. A meeting of the American Pomological Society in conjunction with the Eastern Fruit Growers Association, the Northern Nut Growers Association, and the Society for Horticultural Science, held in November, 1913, brought together in the foyer of the building one of the finest exhibitions of fruit that has ever been displayed in this country.

Respectfully submitted.

RICHARD RATHBUN,
Assistant Secretary in Charge U. S. National Museum.

DR. CHARLES D. WALCOTT,
Secretary of the Smithsonian Institution.

OCTOBER 6, 1914.

APPENDIX 2.

REPORT ON THE BUREAU OF AMERICAN ETHNOLOGY.

SIR: In response to your communication dated July 1, I have the honor to present the following report on the operations of the Bureau of American Ethnology for the fiscal year ending June 30, 1914, conducted in accordance with authority granted by the act of Congress approved June 23, 1913, making appropriations for the sundry civil expenses of the Government, and with a plan of operations submitted by the ethnologist-in-charge and approved by the Secretary of the Smithsonian Institution. The provision of the act authorizing the researches of the Bureau of American Ethnology is as follows:

> American ethnology: For continuing ethnological researches among the American Indians and the natives of Hawaii, including the excavation and preservation of archæologic remains, under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employees and the purchase of necessary books and periodicals, including payment in advance for subscriptions, $42,000.

SYSTEMATIC RESEARCHES.

The systematic researches were conducted by the regular staff of the bureau, consisting of nine ethnologists, including the ethnologist-in-charge and several special investigators. These operations may be summarized as follows:

Mr. F. W. Hodge, ethnologist-in-charge, was occupied during most of the year with the administrative affairs of the bureau. Considerable attention, however, was devoted to the preparation of the annotated bibliography of the Pueblo Indians, which is probably more extensive than that of any other group of tribes, as Pueblo written history commenced in the year 1539, and the writings pertaining thereto are exceedingly voluminous. The bibliography is recorded on cards, the number of which is now about 1,900. The cataloguing of the vast amount of manuscript material bearing on the subject has been somewhat simplified by the recent publication of Bolton's Guide to Materials for the History of the United States in the Principal Archives of Mexico, published by the Carnegie Institution of Washington, and Twitchell's Spanish Archives of New Mexico, although without consultation of the documents themselves it is not possible to give more than the title in most cases. In the spring Mr. Hodge made a brief visit to the library of the Presbyterian Board of Home Missions in New York City, where he was enabled to record the titles of numerous published writings on missionary efforts among the Pueblo Indians of New Mexico, not accessible elsewhere. In this bibliographical work he has had the assistance of Mrs. Frances S. Nichols and Miss Florence M. Poast. Mr. Hodge continued to represent the bureau on the Smithsonian Advisory Committee on Printing and Publication, and the Smithsonian Institution on the United States Board on Geographic Names.

Early in the autumn of 1913 Mr. Hodge made a reconnoissance of a group of ruins, evidently prehistoric, on a mesa rising from the southwestern margin of the Cebollita Valley, about 20 miles south of Grant, Valencia County, N. Mex., and only a few yards from the great lava flow that has spread over the valley to the westward for many miles. While no very definite information regarding the origin of this ruined pueblo has yet been obtained, there is reason to suppose that it was occupied by ancestors of the Tanyi, or Calabash, clan of the Acoma tribe, and is possibly the one known to them at Kowina.

These ruins consist of a number of house groups forming a compound. That the structures were designed for defense is evident, for not only are they situated on an almost impregnable height rising about 200 feet above the valley, but the houses themselves partake of the form of fortifications, while the only vulnerable point of the mesa is protected at the rim by means of a rude breastwork of stones. Moreover, the outer walls of the buildings, some of which still stand to a height of several feet, are pierced only with loopholes, entrance to the structures doubtless having been gained by means of portable ladders, as in some of the pueblos of to-day. The houses of the great compound, consisting of four compact groups of buildings, were evidently "terraced" on the plaza side, the rooms facing this court perhaps having been only a single story in height. As a further protection to the pueblo, the eastern side was defended by a low wall, pierced by three gatewaylike openings, extending from the northeastern to the southeastern corner of the compound.

The rooms indicated in the ground plan of the four house groups number approximately 95 (for the northern group), 58 (eastern group), 32 (central group), and 102 (southeastern group), or an aggregate of 287 rooms. At the time of its occupancy the number of rooms in the compound probably approximated 550. In addition, there are traces of four or five single-story rooms abutting on the defensive wall bounding the northeastern part of the compound. A short distance from the southwestern angle of the southwestern house group are two smaller detached houses, the southernmost one consisting of 24 rooms in a long tier, 2 rooms deep, extending approximately NNW. and SSE. The other structure, about 55 feet north-westward, is rectangular and contains 11 rooms in its ground plan. Four kivas are traceable among the rooms of the main compound—one in the northwestern, one in the central, and two in the southwestern group. In each case, so far as is determinable without excavation, the outer walls of the kivas are rectangular, while the inner walls are circular and slightly recessed a short distance above the floor.

About 500 feet southeastward from the main compound, at the edge of the mesa, stand the well-preserved walls of another structure, consisting of a double row of rooms, the outer wall, or that overlooking the mesa rim, extending 28 and 15 feet, respectively, beyond the northwestern and southwestern corners of the building proper, in order to give further protection. The length of this outer wall from angle to angle is about 132 feet. It exhibits one of the finest examples of masonry to be seen in the ancient pueblo ruins of the Southwest, for not only have the building stones been dressed to shape, but their faces have been finished by pecking, with such labor as to confirm the belief that the ancient village was designed for permanent occupancy. The southern corner of the outer defensive wall is not only curved, but the stones of which it is built are rounded by careful pecking, a most unusual feature in pueblo architecture. That this last structure was designed to protect the most vulnerable part of the mesa is evident from the fact that the outer wall is without openings of any kind and extends beyond the rooms of the structure, and because the adjacent mesa rim is protected by a rude low wall, especially at such points as required ready defense against attack from below. As already noted, the walls of these ruins are noteworthy by reason of the excellence of their masonry, special effort having been made to produce a pleasing effect in the exterior faces. Of the inner walls so much can not be said; but as there is no question that when the houses were occupied the rooms were smoothly plastered, there was little need of the elaborate finish accorded the exposed masonry. Slight attention was paid either to regularity in the shape of the stones or to smoothness of surface in building the inner walls, nor was the aboriginal mason more particular in bonding the inner and outer courses than in "breaking" the joints of the outer face. It seems remarkable that, possessed of such patience and expertness as the builders here display in other ways, they seem to have been unaware of the necessity of avoiding the construction of their walls in such manner that in places as many as six or seven vertical joints occur practically in line. In this brief report only mere mention can be made of many other interesting architectural features of these ruins, as well as of another pueblo ruin, more or less circular in shape, situated a few miles northeastward on a low mesa at the extreme head of Cebollita Valley, which here forms a small but beautiful canyon.

The inhabitants of the great compound first described obtained their water supply by means of two principal reservoirs fed by the drainage from the great sandstone shelf on the southern slope of the mesa summit. These reservoirs are natural depressions in the rock, but the capacity of the larger one, which measures 35 by 90 feet and is about 5 feet in maximum depth, has been greatly augmented on the western side by an artificial retaining wall 14 feet long and 10 feet in thickness, with an exposed face of 2½ feet on the reservoir side. So well did this reservoir evidently serve the ancient mesa-dwellers, that, during seasons of unusual rain, water still stands to a considerable depth within the depression. The smaller reservoir is triangular in outline and measures about 15 by 19 feet. An interesting feature in connection with the larger reservoir is the remains of a rude dike extending 60 feet along the rocky shelf above referred to, built for the purpose of diverting the flow of rain water from its natural course into the reservoir.

It is not yet known where the ancients of this pueblo customarily buried their dead, but probably the interments were made in the talus of the mesa, as is the case with the Hopi, of Arizona, to-day. There was found, however, in the corner of a shallow cavern in the northern face of the mesa, above the talus, a small cist, formed by a low and broken wall of masonry, which contained the somewhat incomplete skeletons of two adult females, one incomplete skeleton of a boy, and the incomplete and defective skeletons of two infants. With one exception these remains had been greatly disturbed by rats, which had burrowed their way through the bones and their accompaniments to the bottom of the cist and fairly filled the repository with cactus spines, excreta, and other débris of nest building. The remains were accompanied with several pottery vessels, chiefly bowls, one of which was covered with a well-preserved mat, plaited of a fibrous plant which Mr. Lyster H. Dewey, of the Department of Agriculture, identifies as a scirpus, and almost certainly *Scirpus validus*. The ornamentation of this pottery, as well as of the numerous sherds scattered about the ruins, consists of plain red, black on red, white on red, plain black, black on white, brown on white, brown on red, and many other combinations of color. All the decorations noted were in geometrical designs.

On the northern face of the mesa, but practically hidden from view except from one point in the valley below, is a small house shelter of excellent masonry, built beneath an overhanging ledge of the cliff which forms the roof. This shelter, which is provided with a single small opening overlooking the valley to the northward, was seemingly designed as a lookout station either for watching the crops or an approaching foe. Across the valley, on the eastern side of the first great mesa directly opposite that on which the ruins are situated, is another small cliff lodge, now accessible only by artificial means. Examination of the interior, as in the case of the cliff lodge above described, yielded nothing of interest. Farther up the valley, on the northern side, in plain view near the base of a mesa, is a larger cliff lodge, filled to a considerable depth with detritus from the soft stone forming the roof and side walls. Examination of the floor of this lodge a few years ago by Mr. Hodge yielded a few corncobs, one or two small objects made of yucca leaves, and a wooden drumstick of a form such as the Zuñi now employ.

Dr. J. Walter Fewkes, ethnologist, spent the month of July, 1913, in the office continuing the preparation of his monographic report on the aborigines of the West Indies, especially describing the many objects from these islands in the noteworthy collection of George G. Heye, esq., of New York. He made a visit to New York toward the close of the month to study recent additions to this collection and to supervise the preparation of the illustrations for his report. It became necessary, in order to make this memoir as comprehensive as possible, to investigate types of the Guesde collection, now owned by the Museum für Völkerkunde in Berlin. Accordingly Dr. Fewkes went to Europe at his personal expense and spent August, September, and October studying these types and also many undescribed Porto Rican and other West Indian objects in various museums. Drawings of about 140 specimens, many of which have not been described, were made during the course of these studies in Berlin. He also visited the museum at Copenhagen, Denmark, which contains many old specimens from the Danish West Indies and some rare types of prehistoric objects from Porto Rico, all of which were either drawn or photographed. West Indian objects were found also in the museum collections of Leipzig, Dresden, and Vienna. Some time was given to an examination of the dolmens and megaliths in the neighborhood of Berlin and elsewhere in northern Germany, and of the numerous mounds and prehistoric workshops on the island of Rügen in the Baltic Sea.

Dr. Fewkes spent his vacation on the shore of the Mediterranean, which he crossed, visiting the most striking ruins in Egypt, penetrating as far south as Assouan, and making special studies of the remaining evidences of neolithic man at Abydos and El Kab on the banks of the Nile. He had always in mind a study of prehistoric irrigation in this region, with a view to comparing the works with similar remains in Arizona. In the museums at Cairo and Assouan Dr. Fewkes examined considerable material dating back to late neolithic times and found a remarkable similarity not only in architectural features but also in stone implements, basketry, bone implements, and other artifacts from the valley of the Nile and those from our Southwest. One of the important features of the visit to Egypt was a study of methods of excavation and repair of ruins adopted by Egyptologists. On his return from Egypt Dr. Fewkes passed through Greece and southern Italy and was able to acquaint himself with the method of excavation and repair of ancient ruins in these countries, especially those on the Acropolis and at Pompeii.

Dr. Fewkes arrived in Washington in April and immediately resumed work on his report on the Aborigines of the West Indies, which was continued during April and the greater part of May. In the latter month he again took the field and spent the whole of June in archeological research in the Mimbres Valley, N. Mex. In this work he was able to enlarge our knowledge of the distribution of pottery symbols and to add important collections to the National Museum. The Mimbres Valley is practically the northern extension into the United States of an inland basin known in Chihuahua as the Sierra Madre Plateau. The fact that its drainage does not connect with any stream that flows into the Atlantic or the Pacific Ocean imparts a peculiar character to its geographical environment. On the southern part of this plateau, as along the Casas Grandes River, mounds and ruins of large size are well known, from which have been taken some of the finest pottery in the Southwest; but the archeology of the extension of this plateau into New Mexico has never been adequately examined. In his brief reconnoissance Dr. Fewkes collected evidence that the prehistoric culture of the Mimbres Valley was strikingly characteristic. The decorated pottery from the ruins in this valley is unlike that of any other region. It consists mainly of mortuary food bowls, which the prehistoric inhabitants were accustomed to break or "kill" and place over the heads of the deceased, who were buried beneath the floors of the houses. About 60 specimens of beautiful pottery, more than half of which are ornamented with painted figures of human beings and animals, were found or purchased. As these are the first examples ever brought to the National Museum from this region, the results are gratifying. They afford through their geometrical ornamentation, and especially because of the life forms which predominate, an interesting insight into the ancient culture of the Pueblo region to the north and in the Gila Valley to the west. It is Mexican in type, and some of the fragments are practically identical in form and ornamentation with the beautiful pottery from Casas Grandes, Chihuahua.

During the year Dr. Fewkes added about 350 pages of manuscript to his report on the Aborigines of the West Indies, which was approaching completion at the close of the year.

Shortly before the close of the preceding fiscal year Mr. James Mooney, ethnologist, proceeded to the reservation of the East Cherokee Indians in western North Carolina for the purpose of continuing the translation and elucidation of the large body of sacred formulas, written in the Cherokee language and alphabet, which he had obtained from the native priests and their surviving relatives some years ago, and about one-third of which he had already translated, with explanatory notes. In connection with this work a large number of plants noted in the formulas as of medicinal or other value were collected and transferred to the division of botany of the National Museum for scientific identification. In this collection were several specimens of the native corn of the Cherokee, still cultivated as sacred by a few of the old conservatives. On examination by the experts of the Department of Agriculture this corn was found to be a new and hitherto undescribed variety of special food importance under cultivation. Return was made from the field early in October, 1913.

In June, 1914, a brief trip was made into Prince Georges and Charles Counties, Md., for the purpose of investigating the status and origin of some persons of supposedly Indian descent, concerning whom several inquiries had come to the bureau. Mr. Mooney found, as he had supposed, that these people, numbering in all several hundred, were, like the Pamunkey of Virginia and the so-called Croatan of North Carolina, a blend of the three races, Indian, Negro, and White, with the Indian blood probably predominating. They constitute and hold themselves a separate caste, distinct from both white and negro. They probably represent the mongrelized descendants of the Piscataway tribe, and are sometimes locally distinguished among themselves as "We-Sort," that is, "Our Sort."

On June 22, 1914, Mr. Mooney again started for the East Cherokee to continue work on the sacred formulas, with a view to speedy publication.

His time in the office during the winter and spring was occupied chiefly with the extended investigation of former Indian population, together with routine correspondence and replies to letters of inquiry. On request of the Department of Justice he prepared an extended deposition on tribal ranges and Indian depredations in northern Mexico and along the Rio Grande, which was officially characterized as one of the most important and interesting that had ever come before the department.

In pursuance of his investigations of the Creek Indians and allied tribes, Dr. John R. Swanton, ethnologist, proceeded to Oklahoma early in July to attend the busk ceremonies, and was present at those of the Eufaula, Hilibi, Fish Pond, and Tukabachi Creeks. Notes were taken on all of these and photographs obtained of various features of all but the last. At the same time, with the valued assistance of Mr. G. W. Grayson, of Eufaula, Dr. Swanton gathered further ethnological information from some of the old people, and continued this work after the ceremonies ceased. Somewhat later he visited the small body of Indians in Seminole County who still retain a speaking knowledge of Hitchiti, and added about 40 pages of text to that previously obtained, besides correcting a portion of Gatschet's Hitchiti vocabulary. He made an arrangement with an interpreter by which 100 pages of additional text were received after his return to Washington.

While some time was devoted to studies of the Alabama, Hitchiti, and Choctaw languages, most of Dr. Swanton's attention while in the office during the year was centered on two particular undertakings. One of these was the proof reading of the Choctaw-English section of Byington's Choctaw Dictionary, and the compilation, with the efficient help of Miss M. C. Rollins, of an English-Choctaw index, which will comprise about 350 printed pages, to accompany it. The other was work on the first draft of an extended report on the Creek confederacy, of which the historical part, consisting of 300 typewritten pages, is practically completed.

At the beginning of the year Mr. J. N. B. Hewitt, ethnologist, undertook the work of editing and copying the Seneca text "Shagowenotha, or The Spirit of the Tides," which was recorded by him in the form of field notes in 1896 on the Cattaraugus Reservation, New York. This particular piece of work, forming a text of 3,692 native words, was completed in August, 1913. The task of making a literal, almost an etymological, interlinear translation of this text was next undertaken and was completed in November, yielding an aggregate of 11,411 English words in the rendering. The other of the two native texts in Seneca, "Doadanegen and Hotkwisdadegena," which was recorded in the form of field notes by Mr. Hewitt in 1896, was next edited and copied; this work was completed by the close of December and consists of 4,888 native Seneca words. The literal interlinear translation of this text then taken up was completed in February, 1914, making 14,664 English words in the rendering.

On finishing these translations Mr. Hewitt commenced the reading and digesting of the Seneca material of the late Jeremiah Curtin for the purpose of providing notes and explanations to the stories, a task that was made the more difficult by the fact that Mr. Curtin's field notes of explanation and identification are not available. One of the longest of the stories collected by Mr. Curtin, "Doonogaes and Tsodiqgwadon," comprising 149 typewritten pages, required 144 notes varying in length from three or four lines to several pages; but this story is of exceptional length. The entire Curtin material has now been reread and annotated. Mr. Hewitt also completed the notes for his introduction to the "Seneca Myths and Fiction," and the final writing was almost finished by the close of the year.

As opportunity offered, Mr. Hewitt continued to work on a sketch of the Iroquois language, and he has now in hand about 75 pages of manuscript, in addition to a considerable body of notes and diagrams for incorporation into final form.

Mr. Hewitt also made a week's study of the voluminous manuscript "Dictionary of Words that have been Made Known in or Introduced into English from the Indians of North, Central, and South America," compiled by the late William R. Gerard, with a view of ascertaining its value for publication by the bureau. This examination was made difficult by the fact that the compiler of the dictionary had access to many works which were not available for Mr. Hewitt.

Unfortunately the work summarized above was often interrupted, owing to the need of frequently calling on Mr. Hewitt for the preparation of data for replies to correspondents, whose inquiries pertained to linguistic, historical, sociological, and technical matters. In connection with this work there were prepared 110 letters, rarely exceeding a page in length, although some occupied several pages and required considerable study and research in gathering the needed data for reply.

During the year Mr. Francis La Flesche, ethnologist, recorded the rituals and accompanying songs of five additional Osage ceremonies, known as Wáwatho^{n}, Wadóka Weko, Wazhi^{n}gao, Zhi^{n}gázhi^{n}ga Zhazhe Thadse, and Wéxthexthe. Of these the Wáwatho^{n} is complete; the record fills about 150 pages, including songs, diagrams, and illustrations. This ceremony, which is of religious significance and is reverenced by all the people, has been obsolete for about 20 years, and there now remain only two men in the tribe who remember it in most of its details. It was a peace ceremony that held an important place in the great tribal rites of the Osage, for through its influence friendly relations were maintained among the various gentes composing the tribe, and it was also the means by which friendship with interrelated tribes was established and preserved. Early French travelers mention this ceremony as being performed by the Osage in one of the tribes of the Illinois confederacy during the second decade of the eighteenth century. Unlike the Osage war ceremonies, which are complex and composed of several steps or degrees, the Wáwatho^{n} is simple and complete in itself. The "pipes," sometimes called calumets, which are employed in its performance, consist of a number of sacred symbolic articles, each of which, with its attendant ritual, was in the keeping of a certain gens of the tribe. The assembling of these articles formed an essential part of the ceremony, for it was on this occasion that the ritual, which explained both the significance of and the precepts conveyed by the sacred articles, had to be recited. This Wáwatho^{n} ceremony resembled that of the Omaha, Ponca, Oto, and Pawnee tribes, differing only in minor details. To the intelligent thinking class the aims and purposes of the ceremony are clear, but there are among the Osage, as among other tribes, those who can not comprehend fully the deeper, broader teachings of such a rite, and because of this restricted view superstitious beliefs regarding it now prevail among the lower classes.

The record of the Wadóka Weko, one of the seven war ceremonies, consists of 89 pages of manuscript, with 32 songs. This rite, which is the sixth degree of the war ceremony, is divided into eight parts, exclusive of the introductory rites, and consists of rituals and songs pertaining to the ceremonial cutting of the scalps for distribution among the various gentes for their sacred packs. One of these parts has to do with the *odóⁿ*, or "honors," won by the warriors in battle. While this ceremony is recorded completely, it is not yet ready for publication, since it is one of seven interdependent degrees the study of which is not yet finished.

Wazhiⁿgao, the bird ceremony for boys, is another of the seven degrees, and is regarded as important. It has been transcribed in full, but the notes thereon have not yet been elaborated for publication.

Zhiⁿgázhiⁿga Zhazhe Thadse (naming of a child), a ceremony that bears no direct relation to any other, is regarded as essential to the proper rearing of a child, and is still practiced. This ceremony has been recorded in its entirety, but still lacks the descriptive annotation necessary before publication.

The Wéxthexthe, or tattooing ceremony, the last of the five recorded by Mr. La Flesche, was taken down from its recitation by one of the men who had participated therein. This transcription is still, in a measure, fragmentary, but enough has been obtained to render a fair idea of the significance of the tattoo designs employed. The notes on the Wéxthexthe are not yet prepared for publication, as there is still a possibility of recording the ceremony in its entirety. A set of the implements used by the Osage in tattooing have been obtained for illustration and have been deposited in the National Museum. There has also been placed in the museum a waxóbetóⁿga, or great sacred pack, which once belonged to Waçétoⁿzhiⁿga, a prominent man of the tribe, who died in 1910. After much persuasion his widow reluctantly consented to part with this sacred article, together with its buffalo-hair and rush-mat cases. This pack consists of the skin and plumage of a white pelican, the bird which in Osage mythology revealed through a dream the mysteries of tattooing and provided the implements therefor.

All the above-described ceremonies studied by Mr. La Flesche have still a strong hold on the Osage people; this, together with the fact that every initiated person acquired his knowledge at great expense, has made it almost impossible to record the ceremonies in full from those who have been induced to speak about them.

Mrs. M. C. Stevenson, ethnologist, continued her studies of the ethnology of the Tewa Indians of New Mexico, devoting special attention to the pueblo of San Ildefonso, with a view of elaborating her memoir on this group of tribes, which consists of about 400 pages of manuscript, material relating to almost every phase of Tewa customs and beliefs having been added in whole or in part during the course of the year. Perhaps the most important of the new data gathered by Mrs. Stevenson on these interesting sedentary people relate to their ceremonies with respect to human sacrifice. The conservatism of the Tewa and the secrecy with which most of their numerous rites are conducted make them a difficult subject of study and one requiring considerable time. Mrs. Stevenson's memoir had reached such a stage of completion that at the close of the year she was making final arrangements for acquiring the materials still needed for illustrations.

Shortly after the beginning of the fiscal year Dr. Truman Michelson, ethnologist, proceeded to Tama, Iowa, to renew his researches among the Fox Indians. After successfully commencing these studies he proceeded to Tongue River Reservation in Montana for the purpose of studying the remnant of the Sutaio tribe incorporated with the Cheyenne. It seems that some ethnological information can still be obtained in regard to specific Sutaio matters, but little of the language remains. Dr. Michelson compiled a fairly large Sutaio vocabulary, but fewer than a dozen words are fundamentally different from the corresponding Cheyenne terms. Such grammatical forms as could be obtained indicate that Sutaio sheds little or no light on the divergent Algonquian type of the Cheyenne language.

Returning to Tama to renew his Fox studies, Dr. Michelson succeeded in elucidating the social organization almost to completeness. It appears that the two major divisions of the tribe are not purely for rivalry in athletics, but rather are ceremonial. Dr. Michelson was successful also in obtaining the very long myths of the culture hero and the Mother of all the Earth. It is evident that the actual Fox society still corresponds in a measure to that given in the myths.

In October Dr. Michelson proceeded to Kansas to investigate the Sauk and Fox of the Missouri. A reconnoissance only was made here, and some of the Fox material obtained at Tama was translated. In November he returned to Washington, and in January, 1914, visited the Carlisle Indian School for the purpose of studying special points of grammar and phonetics with some of the Sauk and Fox pupils. Thence he made a trip to New York City, taking with him one of the pupils for the purpose of consulting Dr. Franz Boas, honorary philologist of the bureau, on certain mooted points pertaining to the Fox language. While in New York a few tracings were made with the Rousselot apparatus.

In May Dr. Michelson again visited Carlisle for the purpose of making a translation of the story of a sacred bundle of the Fox Indians, which he has recently procured.

Toward the end of the fiscal year Dr. Michelson devoted some time to the problem whether the Yurok and Wiyot languages of California were Algonquian, as had been recently claimed, and reached the conclusion that the existing evidence does not justify such a classification.

Work on the Handbook of American Indian Languages was continued under the personal direction and editorship of Dr. Franz Boas, honorary philologist. Part 2, which is in preparation, is to contain grammatical sketches of the Takelma, Coos, Siuslaw, and Alsea languages of Oregon; the Kutenai, of Montana; and the Chukchee. The Takelma sketch was published in advance in separate form in 1912. During the present year the printing of the sketch of the Coos, by Leo J. Frachtenberg, which forms pages 297–429 of part 2, was finished. The manuscript of the Siuslaw, also by Dr. Frachtenberg, was completed and revised, and, except for a small part, is in galley form. The Chukchee sketch likewise has been set up in galleys and revised, and new material on the dialects of the language, having become available, has been added. The printing of the sketch proceeded necessarily slowly, since the notes had to be read by the author, Mr. Waldemar Bogoras, who lives in Russia. A full treatment of this grammar is particularly desirable, since it serves to define the relationships of the American languages toward the west. Dr. Frachtenberg, a fuller report of whose work will follow, has made progress with his studies of the Alsea. The grammatical material and the texts have been extracted and studied, and the latter, which are to form the basis of the sketch, have been copied for the printer. Dr. A. F. Chamberlain, a valued collaborator, whose untimely death we lament, furnished a sketch of the Kutenai language. It was necessary to make a detailed study of this sketch. This was done by Dr. Boas partly during the winter in New York with the help of a Kutenai boy and partly during the month of June among the Indians of Montana and British Columbia. The report on this sketch was completed. A certain amount of preparatory work for the sketch of the Salish language was also done, more particularly a map showing the distribution of the Salish dialect, based on researches by James Teit, was completed. The expense of the field work for this map, which has occupied four years, was met by Mr. Homer E. Sargent, of Chicago, to whose lively interest in the Handbook and related subjects we are deeply indebted. The vocabularies on which the map is based are in an advanced stage of preparation.

Much time was devoted by Dr. Boas during the year to the preparation of a report on the mythology of the Tsimshian Indians, based on material written during a period of 10 years by Henry W. Tate, himself a Tsimshian. Owing to his recent death it was necessary to close the collection, the expenses of which have been defrayed from private sources. The monograph was completed and is in type for publication in the thirty-first annual report.

Brief reference to the researches of Dr. Leo J. Frachtenberg, ethnologist, has been made in connection with the preparation of part 2 of the Handbook of American Indian Languages. The beginning of the fiscal year found Dr. Frachtenberg in the field in Oregon, where, from June to September he was engaged in linguistic and ethnologic work on the Kalapooian family. During these months he collected a number of grammatical notes and nine texts in the dialect of the so-called Calapooia Proper, but owing to lack of sufficient means for continuing this field work he was compelled to discontinue it in October. The linguistic researches into the Kalapooian family brought out a number of interesting points, of which the most salient are as follows: Phonetically the family is related closely to the Lutuamian (Klamath) and Sahaptin groups. Certain pronominal forms and a few numerical terms are identical with the Klamath and Sahaptin forms. In all other respects, chiefly morphological, Kalapooian bears close resemblance to the Coos, Siuslaw, and Yakonan stocks. A particularly close affiliation exists between this and the Coos family in the phonetic structure of words. While the phonetics of both languages are divergent, both are what may be termed vocalic languages and are practically free from any difficult consonantic clusters. The Calapooia texts thus far obtained deal chiefly with the Coyote cycle and are identical with myths found among the Coos, Molala, Klamath, Maidu, Chinook, Alsea, Takelma, Salish, and other tribes of the Pacific area. The mythology as a whole is typical of that region in the absence of true creation myths and in the multitude of transformation stories.

A survey of the linguistic phase of the Kalapooian stock shows it to embrace the following dialects: Calapooia Proper (also called Marysville), Chelamela, Yamhill, Atfalati, Wapato Lake, Ahantsayuk, Santiam, Lakmayut, and Yonkallat. These dialects show certain degrees of interrelationship, which may be formulated as follows: Calapooia, Santiam, Lakmayut, and Ahantsayuk form one closely related group; another group embraces the Yamhill and Atfalati dialects, while Yonkallat seems to constitute a group of its own. No information as to the Chelamela dialect could be obtained.

In July Dr. Frachtenberg received what seemed to be trustworthy information that some Willapa Indians were still living at Bay Center, Wash., but on visiting that point he found the reputed Willapa to be in fact members of the Chehalis tribe, thus proving conclusively that the Willapa are entirely extinct.

Dr. Frachtenberg returned to New York late in October and was engaged until the beginning of December in the preparation of the Siuslaw grammatical sketch for the Handbook of American Indian Languages, additional work on which became necessary because of the fact that during his stay in the field he had received further information concerning this extinct stock. In December Dr. Frachtenberg took up his duties in Washington, becoming first engaged in supplying references from the Siuslaw texts in the grammatical sketch of that language. At the close of the year this sketch was in type. Dr. Frachtenberg also prepared for publication a Siuslaw-English and English-Siuslaw vocabulary, containing 90 typewritten pages. He furthermore prepared an English-Coos glossary, which may be utilized in the near future, as it has been found desirable to add such a glossary to each volume of native texts.

On completion of this work Dr. Frachtenberg commenced the preparation of the Alsea texts collected by Dr. Livingston Farrand in 1900 and by himself in 1910. These texts, consisting of 31 myths, tales, and narratives, and comprising 195 typewritten pages, will be submitted in the near future with a view to publication as a bulletin of the bureau.

At the close of the fiscal year Dr. Frachtenberg was preparing for another field season in Oregon, with the view of finishing his studies of the Kalapooian stock and of conducting similar researches among the Quileute.

Mr. W. H. Holmes, of the National Museum, continued his work on the preparation of the Handbook of American Antiquities for the bureau, reaching the practical completion of part 1 and making much headway in the preparation of part 2; progress in this work, however, was necessarily delayed owing to the pressure of many duties connected with a head curatorship in the National Museum.

During August, 1913, Mr. Holmes made a visit to Luray, Va., for the further study of an ancient village site near that place and the examination of certain implement-making sites in the vicinity. In June he visited Missouri for the purpose of studying certain collections owned in St. Louis and for the reexamination of an ancient iron and paint mine at Leslie. It was found, however, that recent mining operations had been carried so far that traces of the aboriginal work at the mine were practically obliterated, and besides the mine was found to be filled with water, making effective examination impossible. From St. Louis he proceeded to Chicago, where studies were made of certain collections with a view of obtaining data necessary to the completeness of the Handbook of American Antiquities.

In her studies of Indian music Miss Frances Densmore made two trips to the Standing Rock Reservation, S. Dak. (one in July and August, 1913, and one in June, 1914), where she engaged in investigations at Bullhead, McLaughlin, and the vicinity of the Martin Kenel School. This research completed the field work for the proposed volume of Sioux music, the material for which, subsequently prepared for publication, consists of 323 pages of manuscript, 98 musical transcriptions of songs, 20 technical analyses of songs, and 33 original illustrations.

The practical use which musical composers are making of the results of Miss Densmore's studies is very gratifying. Mr. Carl Busch has adapted for orchestral purposes four of the songs rendered by Miss Densmore and published by the bureau, as follows: (1) Chippewa Vision, (2) Farewell to the Warriors, (3) Love Song, (4) Lullaby. Mr. Heinrich Hammer, of Washington, has composed a Sun Dance Rhapsody and a Chippewa Rhapsody. Mr. Charles Wakefield Cadman has composed, for the voice, two of the Chippewa songs, "From the Long Room of the Sea" and "Ho, Ye Warriors on the Warpath." Mr. S. N. Penfield has harmonized two vocal quartets, "Manitou Listens to Me" and "Why Should I be Jealous?" For the violin Mr. Alfred Manger has prepared a "Fantasie on Sioux Themes," and Mr. Alberto Bimboni has well advanced toward completion an opera bearing the title "The Maiden's Leap." Certain of the orchestral arrangements have been played by the Chicago Symphony Orchestra (formerly known as the Thomas Orchestra), as well as by the symphony orchestras of Washington, Minneapolis, and Kansas City. It is interesting to note the demand for Sioux themes in advance of their publication. These have been furnished in manuscript as far as possible to those desiring them for specific and legitimate use. Two of the compositions in the foregoing list are based on such themes.

Work on the volume of Sioux music is approaching completion. This will be larger than either of the bulletins on Chippewa music, and, while the same general plan has been followed, there will be much that is new, both in subject matter and in style of illustration.

During the year work on the Handbook of Aboriginal Remains East of the Mississippi was continued by Mr. D. I. Bushnell, jr., under a small allotment from the bureau, and approximately 90,300 words of manuscript were recorded on cards geographically arranged. The entire amount of manuscript now completed is about 321,000 words, and the bibliography thus far includes 306 titles. As a result of the notes received from the Wisconsin Archeological Society, through the courtesy of its secretary, Mr. Charles E. Brown, of Madison, every county of that State will be well represented in the Handbook. It is to be regretted that more information regarding aboriginal remains is not forthcoming from certain other parts of the country east of the Mississippi, especially the New England States, which at this writing are not adequately represented. The bureau is indebted to Mr. Warren K. Moorehead, of the department of archeology of Phillips Academy, Andover, Mass., for the generous use of original data gathered by him in Maine in advance of its publication by the academy.

Mr. James Murie, as opportunity offered and the limitations of a small allotment made by the bureau for these studies allowed, continued his observations on the ceremonial organization and rites of the Pawnee tribe, of which he is a member. The product of Mr. Murie's investigation of the year, which was practically finished but not received in manuscript form at the close of June, is a circumstantial account of "The Going After the Mother Cedar Tree by the Bear Society," an important ceremony which has been performed only by the Skidi band during the last decade.

In the last annual report attention was directed to a proposed series of handbooks of the Indians of the several States and to the arrangements that had been made for such a volume, devoted to the tribes of California, by Dr. A. L. Kroeber, of the University of California. The author has submitted sections of the manuscript of this work for suggestion, and, although his university duties have delayed its completion, there is every reason to believe that when the material is finished and published it will form an excellent model for the entire series. It has been hoped that the pecuniary means necessary for the preparation of these State handbooks would be provided in accordance with the estimate of an appropriation submitted for this purpose, but unfortunately the desired provision was not made.

Prof. Howard M. Ballou, of Honolulu, has submitted from time to time additional titles for the List of Works Relating to Hawaii, compiled in collaboration with the late Dr. Cyrus Thomas. The material for this bibliography is in the hands of Mr. Felix Neumann for final editorial revision, and it is expected that the entire manuscript will soon be ready for composition.

The large collection of manuscripts in possession of the bureau has been in continuous charge of Mr. J. N. B. Hewitt. A few noteworthy additions were made during the year besides those prepared or which are in process of preparation by members of the staff. Among these may be mentioned the "Dictionary of Words that have been Made Known in or Introduced into English from the Indians of North, Central, and South America," by the late William R. Gerard, a work requiring many years of assiduous labor. The manuscript was acquired for a nominal consideration from Mrs. Gerard, and it is the design to publish the dictionary as soon as it can be given the customary editorial attention. Before his death

Mr. Gerard presented to the bureau an original manuscript of 31 pages, with 21 diagrams, on "Terminations of the Algonquian Transitive and Indefinite Verbs and their Meanings," to which Dr. Truman Michelson has appended a criticism.

Additional manuscripts worthy of special note are the following:

J. P. Dunn: Translation of Miami-Peoria Dictionary, Part 2, *Aller* to *Assomer*. The original of this dictionary is in the John Carter Brown Library, of Providence, through whose courteous librarian, Mr. George Parker Winship, the bureau has been provided with a photostat copy.

J. P. Dunn: Translation of the History of Genesis, second chapter, from the Miami-Peoria Dictionary above cited.

Cyrus Byington: Manuscript notebook, 1844–1848 and 1861. Kindly presented by Mrs. Eliza Innes, daughter of this noted missionary to the Choctaw.

James A. Gilfillan: Chippewa Sentences. A small quarto notebook kindly presented by Miss Emily Cook, of the Office of Indian Affairs.

Parker Marshall: Various memoranda on the location of the Natchez Trace.

H. A. Scomp: Comparative Choctaw and Creek Dictionary, consisting of 1,054 sheets, 20 by 36 inches.

Francisco Pareja: Confessionario, in Spanish and Timuqua. Photostat copy furnished by the courtesy of the New York Historical Society.

Francisco Pareja: Catechismo, in Timuqua. Photostat copy furnished by the courtesy of the New York Historical Society.

Francisco Pareja: Explicacion de la Doctrina, in Timuqua. Photostat copy furnished by the courtesy of the New York Historical Society.

V. C. Fredericksen: Origin of the Eskimo and their Wanderings, with photographs. (The author is a Danish missionary in Greenland.)

From time to time the bureau has been put to considerable expense in having photostat copies made of unique manuscripts and of excessively rare books indispensable to its researches. It is therefore fortunate that the opportunity was afforded, late in the fiscal year, to acquire a photostat apparatus which has since been in constant service. The urgent need of such an instrument was made especially manifest when the Rev. George Worpenberg, S. J., librarian of St. Marys College, St. Marys, Kans., generously accorded the bureau the privilege of copying a number of valuable original linguistic manuscripts in the archives of the college, pertaining chiefly to the Potawatomi and including a dictionary and a grammar recorded by the late Father Maurice Gailland. Manuscript copies of these voluminous linguistic works could have been made only after infinite labor by an expert and at an expense far exceeding the entire cost of the photostat apparatus. By the close of the year the making of the facsimile reproductions had been commenced by Mr. Albert Sweeney, under the immediate direction of Mr. De Lancey Gill, illustrator.

An opportunity was afforded at the close of the year to replace the wooden partition and ceiling of the manuscript room with terra cotta and to install a fireproof door and window coverings, thus giving for the first time adequate protection to the bureau's large collection of priceless unpublished material.

PUBLICATIONS.

The editorial work of the bureau has been continued by Mr. J. G. Gurley, editor, who has been assisted from time to time by Mrs. Frances S. Nichols. The following publications were received from the press during the year:

Bulletin 53, "Chippewa Music—II," by Frances Densmore.

Bulletin 56, "Ethnozoology of the Tewa Indians," by Junius Henderson and John P. Harrington.

"*Coos: An Illustrative Sketch*," by Leo J. Frachtenberg. Extract from Handbook of American Indian Languages (Bulletin 40), part 2.

The status of other publications, now in press, is as follows:

The proof reading of the *Twenty-ninth Annual Report*, the accompanying paper of which, entitled "Ethnogeography of the Tewa Indians," by John P. Harrington, is an exhaustive memoir presenting many technical difficulties, was nearly completed during the year. About two-thirds of the memoir is in page form.

The *Thirtieth Annual Report* comprised originally, in addition to the administrative section, three memoirs: (1) "Tsimshian Mythology," by Franz Boas; (2) "Ethnobotany of the Zuñi Indians," by Matilda Coxe Stevenson; (3) "An Inquiry into the Animism and Folk-lore of the Guiana Indians," by Walter E. Roth. Extensive additions to the first-named memoir, received after the report had been put into type, necessitated the division of the contents, and accordingly this section was transferred to the *Thirty-first Report*. Approximately two-thirds of "Tsimshian Mythology" has been paged, and the Zuñi memoir also, now the first accompanying paper of the *Thirtieth Annual*, is in process of paging.

To the *Thirty-second Report* will be assigned a memoir entitled "Seneca Myths and Fiction," collected by Jeremiah Curtin and J. N. B. Hewitt and edited with an introduction by the latter, the manuscript of which is about ready for editorial revision.

Bulletin 40 (*pt. 2*), "Handbook of American Indian Languages." The work on this bulletin has been carried along steadily under the immediate supervision of its editor, Dr. Boas. Two sections—Takelma and Coos—have been issued in separate form (aggregating 429 pages), and two additional sections, dealing with the Chukchee and Siuslaw languages, respectively, are in type, the former being "made up" to the extent of about 50 pages.

Bulletin 46, "A Dictionary of the Choctaw Language," by Cyrus Byington (edited by John R. Swanton and Henry S. Halbert). The first (Choctaw-English) section of this work was completed during the year and is practically ready for the press. The manuscript of the second section (English-Choctaw directory), comprising 36,008 entries on cards, was sent to the Printing Office April 30 to June 13, but no proof had been received at the close of the year.

Bulletin 55, "Ethnobotany of the Tewa Indians," by Wilfred W. Robbins, John P. Harrington, and Barbara Freire-Marreco. After this bulletin was in type it was found advisable to incorporate a considerable amount of valuable material, subsequently gathered and kindly offered by Miss Freire-Marreco. The change involved recasting in a large measure the original work. The second galley proof is in the hands of Miss Freire-Marreco for final revision.

Bulletin 57, "An Introduction to the Study of the Maya Hieroglyphs," by Sylvanus Griswold Morley. The manuscript and illustrations of this memoir were submitted to the Public Printer the latter part of April. Engraver's proof of the illustrations, with the exception of a few pieces of color work, have been received and approved. Owing to the heavy pressure of public business, the Printing Office had been unable to furnish proof of the letterpress by the close of the year.

Bulletin 58, "List of Publications of the Bureau of American Ethnology." The page proof of this bulletin is in the hands of the printers for slight correction, preparatory to placing it on the press.

The total number of publications of the bureau distributed during the year was 12,819, classified as follows:

Report volumes and separate papers	2,810
Bulletins	9,943
Contributions to North American Ethnology	22
Introductions	5
Miscellaneous publications	39
Total	12,819

As during several years past the extensive correspondence arising from the constant demand for the publications of the bureau has been in immediate and efficient charge of Miss Helen Munroe and Mr. E. L. Springer, of the Smithsonian Institution, assisted by Mr. Thomas F. Clark, jr. The distribution of publications has been made in accordance with law and with entire satisfaction by the office of the superintendent of documents on order of the bureau.

ILLUSTRATIONS.

The preparation of the illustrations for the publications of the bureau, the making of photographs of the members of delegations of Indians visiting Washington, and the developing and printing of negatives made by the staff of the bureau during the prosecution of their field work have been in charge of Mr. DeLancey Gill, illustrator, assisted successively by Mr. Walter Stenhouse and Mr. Albert Sweeney. In addition the numerous photostat copies of manuscripts and books, aggregating about 2,500 exposures, have been made under Mr. Gill's supervision, as elsewhere mentioned. Of the visiting deputations, representing 17 tribes, 79 photographic exposures were made; 92 negatives of ethnologic subjects were required for reproduction as illustrations; 512 negatives made by the members of the staff in the field were developed and 381 prints made therefrom; 105 photographs were printed for presentation to Indians and 627 for publication, exchange, and special distribution. In addition to the photographic work, which constitutes the major part of the illustrative material required by the bureau, 54 drawings were made for reproduction.

The series of photographs, representing 55 tribes, which had been exhibited by the New York Public Library and the Public Library Commission of Indiana, was borrowed in June by the Providence Public Library for a similar purpose.

LIBRARY.

The reference library of the bureau, which consists of 19,240 books, about 12,894 pamphlets, and several thousand unbound periodicals, has been in continuous charge of Miss Ella Leary, librarian, assisted by Mrs. Ella Slaughter. During the year 708 books were accessioned, of which 143 were acquired by purchase and 137 by gift and exchange, the remaining 428 being represented by volumes of serials that hitherto had been neither bound nor recorded. The periodicals currently received numbered 629, of which only 16 were obtained by purchase, the remainder being received through exchange. Of pamphlets, 150 were acquired. During the year 1,195 volumes were sent to the bindery and of these 695 were bound and returned to the bureau.

The endeavor to supply deficiencies in the sets of publications of institutions of learning has continued without remission. Among the more important accessions of this kind during the year were Zeitschrift der Gesellschaft für Erdkunde zu Berlin, 20 volumes; Instituto Geografico Argentino, Boletin, 10 volumes; and Königliches Museum für Völkerkunde, Veröffentlichungen, 8 volumes.

The librarian has prepared a monthly bulletin of accessions for the use of the staff, and has furnished information and compiled bibliographic notes for the use of correspondents. In addition to the constant drafts on the library of the bureau requisition was made on the Library of Congress during the year for an aggregate of 300 volumes for official use, and in turn the bureau library was frequently consulted by officers of other Government establishments.

An appropriation having been made by Congress, in behalf of the Institution, for installing modern steel bookstacks in the eastern end of the large exhibition hall on the first floor of the Smithsonian building, and provision having been made for affording the proposed increased facilities to the library of the bureau, which for four and a half years had been installed in the eastern galleries of the hall mentioned, the books therein were removed in February to the gallery and main floor of the western end of the hall and the eastern galleries were demolished. Although this work of removal occupied two weeks, it was done without confusion and practically without cessation of the library's activities. The new stacks were in process of erection before the close of the fiscal year.

COLLECTIONS.

The following collections were acquired by the bureau or by members of its staff, and, having served the purpose of study, were transferred to the National Museum, as required by law:

Eight fragments of ancient British pottery. Gift to the bureau by Rev. Robert C. Nightingale, Swaffam, Norfolk, England. (55735.)

Potsherds, fragments of human bones, and three heads. Gift to the bureau by Mrs. Bruce Reid, Port Arthur, Tex. (55758.)

Parts of five skeletons (three complete skulls and fragments of two skulls) from a burial cist in a cave about 20 miles south of Grant, N. Mex. Collected by F. W. Hodge, Bureau of American Ethnology. (56134.)

Thirty-one ethnological objects from the Cherokee and Catawba Indians. Collected by James Mooney, Bureau of American Ethnology. (56812.)

Six photographs of Aztec antiquities. Purchased from W. W. Blake, City of Mexico. (56609.)

Stone phallus from Mesa Verde, Colo. Gift to the bureau by H. C. Lay, Telluride, Colo. (56719.)

Arrow point found on the north fork of Roanoke River, about 3 miles from Blacksburg, Va. Gift to the bureau by Prof. Otto C. Burkhart, Virginia Polytechnic Institute, Blacksburg, Va. (56679.)

PROPERTY.

The principal property of the bureau consists of its library, comprising approximately 35,000 books and pamphlets, a large collection of manuscripts for reference or in process of preparation for publication, and several thousand photographic negatives. With the exception of a portion of the library, this material could not be duplicated. In addition, the bureau possesses a photostat apparatus with electric-light equipment, several cameras, dictagraphs, and other appliances for use in conducting scientific research in the field and the office, necessary office furniture and equipment, and a limited supply of stationery, supplies, etc. Also under control of the bureau, but in immediate custody of the Public Printer, as required by law, is a stock of numerous publications, chiefly annual reports and bulletins.

MISCELLANEOUS.

Quarters.—The only improvements made in the quarters occupied by the bureau in the Smithsonian building, as set forth in the last report, have been those incident to the reconstruction of the library and the fireproofing of the manuscript room, above alluded to, and the painting of the walls of four rooms, made necessary partly by inadequate lighting. In addition to the space previously occupied, a room on the fourth floor of the eastern end of the Smithsonian building was assigned temporarily to the bureau for the use of two members of its staff.

Office force.—The personnel of the office has remained unchanged, with the exception of the resignation of one messenger boy and the appointment of another. It has been necessary to employ a copyist from time to time in connection with the editing of Byington's Choctaw Dictionary. The correspondence of the bureau has been conducted in the same manner as set forth in the last annual report and as hereinbefore mentioned.

Recommendations.—The chief needs of the Bureau of American Ethnology lie in the extension of its researches to fields as yet unexploited. Attention has frequently been called to the necessity of pursuing studies among Indian tribes which are rapidly becoming extinct, or modified by their intimate contact with civilization. These researches can not be conducted unless the means are provided, since the present limited scientific corps, with inadequate allotments of money to meet the expenses of extended field investigations, is not equal to the immense amount of work to be done. Unfortunately many opportunities for conducting these researches which were possible a few years ago have passed away, owing to the death of older Indians who alone possessed certain knowledge of their race. Much can still be done, however, if only the means are afforded.

It is scarcely necessary to repeat, in connection with this general recommendation, the estimate for an increase, amounting to $24,800, in the appropriation for the bureau and the brief reasons for urging the grant of this additional sum, inasmuch as these items will be found in the printed Estimates of Appropriations, 1915–16.

Respectfully submitted.

F. W. Hodge,
Ethnologist-in-charge.

The Secretary of the Smithsonian Institution.

APPENDIX 3.

REPORT ON THE INTERNATIONAL EXCHANGES.

SIR: I have the honor to submit the following report on the operations of the International Exchange Service during the fiscal year ending June 30, 1914:

The congressional appropriation for the support of the service during the year, including the allotment for printing and binding, was $32,200 (the same amount as appropriated for the past six years), and the repayments from private and departmental sources for services rendered aggregated $5,264.18, making the total available resources for carrying on the exchange system $37,464.18.

During the year 1914 the total number of packages handled was 341,667, an increase of 3,046 as compared with the preceding year. The weight of these packages was 566,985 pounds, a decrease of 26,984 pounds.

The number and weight of the packages of different classes are indicated in the following table:

	Packages.		Weight.	
	Sent.	Received.	Sent.	Received.
			Pounds.	*Pounds.*
United States parliamentary documents sent abroad	131,469		94,759	
Publications received in return for parliamentary documents		2,103		9,913
United States departmental documents sent abroad	99,826		199,198	
Publications received in return for departmental documents		8,994		19,080
Miscellaneous scientific and literary publications sent abroad	60,844		130,524	
Miscellaneous scientific and literary publications received from abroad for distribution in the United States		38,431		113,511
Total	292,139	49,528	424,481	142,504
Grand total	341,667		566,985	

In April, 1914, the American-Chinese Publication Exchange Department of the Shanghai Bureau of Foreign Affairs, which was designated a few years ago by the Chinese Government as the depository of the set of United States governmental documents sent to that Government, signified its willingness to accept packages for miscellaneous addresses throughout the Chinese Republic and forward them to their various destinations. Consignments intended for distribution in China are, therefore, now sent in care of that department instead of the Zi-ka-wei Observatory at Shanghai.

In this connection, it is desired to record here the Institution's appreciation of the valuable service rendered by the Zi-ka-wei Observatory in the distribution of exchanges to correspondents in China for nearly a quarter of a century.

The Smithsonian Institution, through the International Exchange Service, continues to solicit publications for both foreign and domestic governmental and scientific establishments. At the request of the British ambassador, which was referred to this Institution by the Department of State, many United States official publications were procured for the various Canadian departments and bureaus. As formerly, aid has been rendered the Library of Congress in obtaining from foreign Governments certain documents especially desired for its collections.

Of the 2,465 boxes used in forwarding exchanges to foreign agencies for distribution, 280 boxes contained full sets of United States official documents for authorized depositories and 2,185 were filled with departmental and other publications for depositories of partial sets and for miscellaneous correspondents. The number of boxes sent to each foreign country and the dates of transmission are shown in the following table:

Consignments of exchanges for foreign countries.

Country.	Number of boxes.	Date of transmission.
ARGENTINA	45	July 28, Aug. 22, Sept. 30, Oct. 27, Nov. 29, 1913; Jan. 20, Feb. 26, Apr. 9, June 3, 1914.
AUSTRIA	91	July 16, Aug. 12, Sept. 17, Oct. 15, Nov. 12, Dec. 10, 1913; Jan. 14, Feb. 18, Mar. 18, Apr. 17, May 19, June 17, 1914.
BELGIUM	64	July 19, Aug. 8, Sept. 5, 27, Oct. 11, Nov. 8, 29, Dec. 20, 1913; Jan. 24, Feb. 19, Mar. 21, Apr. 23, May 21, June 29, 1914.
BOLIVIA	6	July 30, Oct. 4, Nov. 26, 1913; Feb. 4, Mar. 7, June 30, 1914.
BRAZIL	32	July 28, Aug. 22, Sept. 30, Oct. 27, Nov. 29, 1913; Jan. 20, Feb. 26, Apr. 9, June 3, 1914.
BRITISH COLONIES	20	July 18, Aug. 2, 23, Sept. 6, 20, Oct. 10, 24, Nov. 14, 21, Dec. 5, 1913; Jan. 10, 24, Feb. 6, Mar. 14, Apr. 4, 18, May 2, 24, June 6, 27, 1914.
BRITISH GUIANA	4	Nov. 5, Dec. 17, 1913; Mar. 14, June 30, 1914.
BULGARIA	6	Oct. 23, Nov. 25, 1913; Feb. 7, Mar. 14, May 14, June 24, 1914.
CANADA	5	Sept. 22, 1913; Jan. 12, Feb. 21, Apr. 14, May 12, 1914.
CHILE	23	July 29, Aug. 3, Sept. 30, Oct. 27, Nov. 28, 1913; Jan. 20, Feb. 27, Apr. 17, June 4, 1914.
CHINA	38	July 30, Aug. 31, Sept. 30, Nov. 15, 1913; Jan. 8, Mar. 9, Apr. 29, May 21, June 16, 1914.
COLOMBIA	16	July 30, Nov. 26, 1913; Jan. 21, May 14, June 24, 1914.
COSTA RICA	16	July 30, Oct. 6, Nov. 26, 1913; Jan. 21, Mar. 7, May 28, June 30, 1914.
CUBA	5	Sept. 22, 1913; Jan. 12, Feb. 21, Apr. 14, May 12, 1914.
DENMARK	40	July 22, Aug. 19, Sept. 23, Oct. 21, Nov. 19, Dec. 20, 1913; Jan. 29, Feb. 21, Mar. 25, Apr. 24, May 27, June 25, 1914.

Consignments of exchanges for foreign countries—Continued.

Country.	Number of boxes.	Date of transmission.
Ecuador	7	July 30, Oct. 6, Nov. 26, 1913; Feb. 4, Mar. 7, May 21, June 30, 1914.
Egypt	11	Sept. 11, Oct. 25, Nov. 29, Dec. 30, 1913; Jan. 23, Feb. 21, Apr. 3, 28, June 10, 1914.
France	180	July 10, 31, Aug. 14, 28, Sept. 18, Oct. 8, 29, Nov. 19, Dec. 3, 24, 1913; Jan. 14, Feb. 4, 18, Mar. 11, Apr. 8, May 6, June 10, 1914.
Germany	433	July 1, 8, 15, 22, 29, 30, Aug. 5, 12, 19, 26, 29, Sept. 2, 9, 16, 23, 30, Oct. 7, 14, 21, 28, Nov. 4, 11, 19, 26, Dec. 2, 9, 16, 23, 30, 1913; Jan. 6, 13, 20, 27, Feb. 3, 10, 17, 24, Mar. 3, 10, 17, 24, 30, Apr. 7, 15, 28, May 5, 12, 26, June 2, 16, 23, 30, 1914.
Great Britain and Ireland.	448	July 12, 18, 25, Aug. 2, 8, 15, 23, 29, Sept 6, 12, 20, 26, Oct. 3, 10, 17, 24, Nov. 1, 7, 14, 21, 29, Dec. 5, 12, 19, 27, 1913; Jan. 3, 10, 17, 24, 31, Feb. 6, 13, 20, 27, Mar. 6, 14, 20, 27, Apr. 4, 11, 18, 25, May 2, 9, 23, June 1, 6, 13, 20, 26, 1914.
Greece	16	July 22, Aug. 23, Sept. 25, Oct. 13, Dec. 17, 1913; Jan. 31, Mar. 7, May 15, June 23, 1914.
Guatemala	7	July 30, Oct. 6, Nov. 28, 1913; Feb. 4, Mar. 7, May 21, June 30, 1914.
Haiti	5	Sept. 22, 1913; Jan. 12, Feb. 21, Apr. 14, May 12, 1914.
Honduras	5	Aug. 28, Nov. 15, 1913; Feb. 5, Mar. 7, June 12, 1914.
Hungary	39	July 16, Aug. 12, Sept. 17, Nov. 12, Dec. 10, 1913; Jan. 14, Feb. 18, Mar. 18, Apr. 17, May 19, June 17, 1914.
India	50	July 12, 18, 25, Aug. 2, 15, 23, Sept. 6, 20, 26, Oct. 10, 17, 24, Nov. 14, Dec. 5, 19, 1913; Jan. 3, 10, 24, Feb. 6, 13, 20, Mar. 6, 14, 20, 27, Apr. 11, 25, May 2, 23, June 6, 20, 25, 1914.
Italy	86	Aug. 7, Sept. 11, 27, Oct. 11, 25, Nov. 8, 29, Dec. 30, 1913; Jan. 23, Feb. 21, Mar. 7, Apr. 28, June 30, 1914.
Jamaica	7	Aug. 27, Oct. 30, Nov. 29, Dec. 7, 1913; Mar. 20, June 12, 25, 1914.
Japan	54	July 24, Aug. 20, Sept. 24, Oct. 23, Nov. 25, Dec. 20, 1913; Jan. 27, Feb. 24, Apr. 28, June 5, 1914.
Korea	4	Aug. 27, Oct. 31, 1913; Feb. 7, June 12, 1914.
Liberia	5	July 31, Oct. 31, Nov. 29, 1913; Mar. 7, May 14, 1914.
Lourenço Marquez	4	Aug. 27, Dec. 17, 1913; June 18, 1914.
Manitoba	5	Sept. 22, 1913; Jan. 12, Feb. 21, Apr. 14, May 12, 1914.
Mexico	5	Sept. 22, 1913; Jan. 12, Feb. 21, Apr. 14, May 12, 1914.
Montenegro	2	Dec. 17, 1913; June 18, 1914.
Netherlands	61	July 15, Aug. 5, 26, Sept. 23, Oct. 14, 28, Nov. 18, Dec. 16, 1913; Jan. 6, Feb 3, 24, Mar. 24, Apr. 21, May 12, June 9, 1914.
Newfoundland	2	Jan. 5, June 30, 1914.
New South Wales	31	July 24, Aug. 20, Sept. 25, Oct. 23, Nov. 22, Dec. 23, 1913; Jan. 27, Feb. 25, Mar. 25, May 7, June 12, 1914.
New Zealand	25	July 24, Aug. 20, Sept. 25, Oct. 23, Nov. 25, Dec. 23, 1913; Jan. 29, Feb. 25, Mar. 27, May 7, June 16, 1914.
Nicaragua	5	Aug. 28, Nov. 15, 1913; Feb. 5, Mar. 7, June 12, 1914.
Norway	31	July 22, Aug. 19, Sept. 23, Oct. 21, Nov. 19, Dec. 20, 1913; Jan. 30, Feb. 21, Mar. 25, Apr. 24, May 28, June 25, 1914.
Ontario	5	Sept. 22, 1913; Jan. 12, Feb. 21, Apr. 14, May 12, 1914.
Palestine	7	Sept. 30, 1913.
Paraguay	5	Aug. 28, Nov. 15, 1913; Feb. 4, May 15, June 30, 1914.
Peru	16	July 29, Aug. 22, Sept. 30, Oct. 27, Nov. 29, 1913; Jan. 20, Feb. 27, June 4, 1914.
Portugal	23	July 22, Aug. 19, Sept. 23, Oct. 21, Nov. 19, Dec. 20, 1913; Jan. 30, Feb. 21, Mar. 25, Apr. 24, May 28, June 25, 1914.
Quebec	5	Sept. 22, 1913; Jan. 12, Feb. 21, Apr. 14, May 12, 1914.
Queensland	13	July 24, Aug. 20, Sept. 25, Oct. 23, Nov. 25, Dec. 23, 1913; Jan. 29, Feb. 25, Mar. 27, May 7, June 16, 1914.

Consignments of exchanges for foreign countries—Continued.

Country.	Number of boxes.	Date of transmission.
ROUMANIA	13	July 31, Aug. 30, Sept. 25, Oct. 23, Nov. 29, 1913; Feb. 7, Mar. 12, May 14, June 24, 1914.
RUSSIA	92	July 17, Aug. 13, Sept. 18, Oct. 16, Nov. 13, Dec. 11, 1913; Jan. 16, 24, Feb. 19, Mar. 19, May 20, June 18, 1914.
SALVADOR	8	July 30, Oct. 6, 24, Nov. 28, 1913; Feb. 4, Mar. 7, June 12, 1914.
SERVIA	13	July 17, Sept. 25, Nov. 15, 1913; Jan. 21, Mar. 7, May 28, June 24, 1914.
SIAM	5	Aug. 27, Nov. 29, 1913; Feb. 7, Mar. 28, June 30, 1914.
SOUTH AUSTRALIA	18	July 24, Aug. 20, Sept. 25, Oct. 23, Nov. 25, Dec. 23, 1913; Jan. 28, Feb. 25, Mar. 27, May 7, June 15, 1914.
SPAIN	30	Aug. 7, Sept. 11, Oct. 25, Nov. 29, Dec. 30, 1913; Jan. 23, Feb. 21, Apr. 3, June 10, 1914.
SWEDEN	72	July 17, Aug. 14, Sept. 18, Oct. 16, Nov. 13, Dec. 11, 1913; Jan. 16, Feb. 19, Mar. 19, Apr. 20, May 20, June 18, 1914.
SWITZERLAND	54	July 19, Aug. 7, Sept. 5, 27, Oct. 11, Nov. 8, 29, Dec. 20, 1913; Jan. 24, Feb. 19, Mar. 21, Apr. 23, May 21, June 19, 1914.
SYRIA	6	Apr. 26, May 27, June 25, 1914.
TASMANIA	12	Aug. 2, 23, Sept. 6, 20, Oct. 24, Nov. 14, Dec. 19, 1913; Feb. 13, Apr. 11, 25, June 25, 1914.
TRINIDAD	3	Mar. 7, 30, June 12, 1914.
TURKEY	14	Aug. 30, Sept. 30, Oct. 23, Nov. 15, 1913; Jan. 8, 23, Feb. 28, Mar. 7, Apr. 30, May 27, June 25, 1914.
UNION OF SOUTH AFRICA.	24	Sept. 25, Oct. 31, Nov. 29, 1913; Jan. 26, Feb. 28, May 13, June 23, 1914.
URUGUAY	21	July 29, Aug. 22, Oct. 4, Nov. 26, 1913; Jan. 21, Feb. 27, June 4, 1914.
VENEZUELA	11	Oct. 4, Nov. 26, 1913; Jan. 21, Mar. 7, May 28, June 30, 1914.
VICTORIA	29	July 24, Aug. 20, Sept. 25, Oct. 23, Nov. 22, Dec. 23, 1913; Jan. 28, Feb. 25, Mar. 27, May 7, June 15, 1914.
WESTERN AUSTRALIA.	24	July 12, 25, Aug. 23, Sept. 6, 20, Oct. 3, 17, 24, Nov. 21, Dec. 5, 19, 1913; Jan. 10, 24, Feb. 6, 20, Mar. 6, 20, Apr. 4, June 13, 1914.
WINDWARD AND LEEWARD ISLANDS.	3	Oct. 31, 1913; Feb. 7, June 12, 1914.

In October, 1913, the New York forwarding agents informed the Institution that boxes 1179 and 1598, which were sent to them under date of March 28 and May 15, 1913, respectively, for transmission to his Japanese Majesty's residency general at Seoul, Korea, had been lost in transit by the steamship company. These consignments contained publications from both governmental and scientific establishments for distribution to Korean correspondents, and duplicates of as many of them as were available for distribution were obtained and forwarded to their destinations.

FOREIGN DEPOSITORIES OF UNITED STATES GOVERNMENTAL DOCUMENTS.

No additions were made to the foreign depositories of full or partial sets during the year, 56 full sets of United States official publications and 36 partial sets now being forwarded regularly to designated depositories abroad.

The recipients of full and partial sets are as follows:

DEPOSITORIES OF FULL SETS.

Argentina: Ministerio de Relaciones Exteriores, Buenos Aires.
Australia: Library of the Commonwealth Parliament, Melbourne.
Austria: K. K. Statistische Zentral-Kommission, Vienna.
Baden: Universitäts-Bibliothek, Freiburg. (Depository of the Grand Duchy of Baden.)
Bavaria: Königliche Hof- und Staats-Bibliothek, Munich.
Belgium: Bibliothèque Royale, Brussels.
Bombay: Secretary to the Government, Bombay.
Brazil: Bibliotheca Nacional, Rio de Janeiro.
Buenos Aires: Biblioteca de la Universidad Nacional de La Plata. (Depository of the Province of Buenos Aires.)
Canada: Library of Parliament, Ottawa.
Chile: Biblioteca del Congreso Nacional, Santiago.
China: American-Chinese Publication Exchange Department, Shanghai Bureau of Foreign Affairs, Shanghai.
Colombia: Biblioteca Nacional, Bogota.
Costa Rica: Oficina de Depósito y Canje Internacional de Publicaciones, San José.
Cuba: Secretaria de Estado (Asuntos Generales y Canje Internacional), Habana.
Denmark: Kongelige Bibliotheket, Copenhagen.
England: British Museum, London.
France: Bibliothèque Nationale, Paris.
Germany: Deutsche Reichstags-Bibliothek, Berlin.
Glasgow: City Librarian, Mitchell Library, Glasgow.
Greece: Bibliothèque Nationale, Athens.
Haiti: Secrétairerie d'État des Relations Extérieures, Port au Prince.
Hungary: Hungarian House of Delegates, Budapest.
India: Department of Education (Books), Government of India, Calcutta.
Ireland: National Library of Ireland, Dublin.
Italy: Biblioteca Nazionale Vittorio Emanuele, Rome.
Japan: Imperial Library of Japan, Tokyo.
London: London School of Economics and Political Science. (Depository of the London County Council.)
Manitoba: Provincial Library, Winnipeg.
Mexico: Instituto Bibliográfico, Biblioteca Nacional, Mexico.
Netherlands: Library of the States General, The Hague.
New South Wales: Public Library of New South Wales, Sydney.
New Zealand: General Assembly Library, Wellington.
Norway: Storthingets Bibliothek, Christiania.
Ontario: Legislative Library, Toronto.
Paris: Préfecture de la Seine.
Peru: Biblioteca Nacional, Lima.
Portugal: Bibliotheca Nacional, Lisbon.
Prussia: Königliche Bibliothek, Berlin.
Quebec: Library of the Legislature of the Province of Quebec, Quebec.
Queensland: Parliamentary Library, Brisbane.
Russia: Imperial Public Library, St. Petersburg.
Saxony: Königliche Oeffentliche Bibliothek, Dresden.
Servia: Section Administrative du Ministère des Affaires Étrangères, Belgrade.
South Australia: Parliamentary Library, Adelaide.

SPAIN: Servicio del Cambio Internacional de Publicaciones, Cuerpo Facultativo de Archiveros, Bibliotecarios y Arqueólogos, Madrid.
SWEDEN: Kungliga Biblioteket, Stockholm
SWITZERLAND: Bibliothèque Fédérale, Berne.
TASMANIA: Parliamentary Library, Hobart.
TURKEY: Department of Public Instruction, Constantinople.
UNION OF SOUTH AFRICA: State Library, Pretoria, Transvaal.
URUGUAY: Oficina de Canje Internacional de Publicaciones, Montevideo.
VENEZUELA: Biblioteca Nacional, Caracas.
VICTORIA: Public Library, Melbourne.
WESTERN AUSTRALIA: Public Library of Western Australia, Perth.
WÜRTTEMBERG: Königliche Landesbibliothek, Stuttgart.

DEPOSITORIES OF PARTIAL SETS.

ALBERTA: Provincial Library, Edmonton.
ALSACE-LORRAINE: K. Ministerium für Elsass-Lothringen, Strassburg.
BOLIVIA: Ministerio de Colonización y Agricultura, La Paz.
BREMEN: Senatskommission für Reichs- und Auswärtige Angelegenheiten.
BRITISH COLUMBIA: Legislative Library, Victoria.
BRITISH GUIANA: Government Secretary's Office, Georgetown, Demerara.
BULGARIA: Minister of Foreign Affairs, Sofia.
CEYLON: United States Consul, Colombo.
ECUADOR: Biblioteca Nacional, Quito.
EGYPT: Bibliothèque Khédiviale, Cairo.
FINLAND: Chancery of Governor, Helsingfors.
GUATEMALA: Secretary of the Government, Guatemala.
HAMBURG: Senatskommission für die Reichs- und Auswärtigen Angelegenheiten.
HESSE: Grossherzogliche Hof-Bibliothek, Darmstadt.
HONDURAS: Secretary of the Government, Tegucigalpa.
JAMAICA: Colonial Secretary, Kingston.
LIBERIA: Department of State, Monrovia.
LOURENÇO MARQUEZ: Government Library, Lourenço Marquez.
LÜBECK: President of the Senate.
MADRAS, PROVINCE OF: Chief Secretary to the Government of Madras, Public Department, Madras.
MALTA: Lieutenant Governor, Valetta.
MONTENEGRO: Ministère des Affaires Étrangères, Cetinje.
NEW BRUNSWICK: Legislative Library, Fredericton.
NEWFOUNDLAND: Colonial Secretary, St. John's.
NICARAGUA: Superintendente de Archivos Nacionales, Managua.
NORTHWEST TERRITORIES: Government Library, Regina.
NOVA SCOTIA: Provincial Secretary of Nova Scotia, Halifax.
PANAMA: Secretaria de Relaciones Exteriores, Panama.
PARAGUAY: Oficina General de Inmigracion, Asuncion.
PRINCE EDWARD ISLAND: Legislative Library, Charlottetown.
ROUMANIA: Academia Romana, Bucharest.
SALVADOR: Ministerio de Relaciones Exteriores, San Salvador.
SIAM: Department of Foreign Affairs, Bangkok.
STRAITS SETTLEMENTS: Colonial Secretary, Singapore.
UNITED PROVINCES OF AGRA AND OUDH: Under Secretary to Government, Allahabad.
VIENNA: Bürgermeister der Haupt- und Residenz-Stadt.

INTERPARLIAMENTARY EXCHANGE OF OFFICIAL JOURNALS.

A list of the countries which have entered into interparliamentary exchange of official journals with the United States is given below:

Argentine Republic.
Australia.
Austria.
Baden.
Belgium.
Brazil.
Buenos Aires, Province of.
Canada.
Cuba.
Denmark.
France.
Great Britain.
Greece.
Guatemala.
Honduras.
Hungary.
Italy.
Liberia.
New South Wales.
New Zealand.
Portugal.
Prussia.
Queensland.
Roumania.
Russia.
Servia.
Spain.
Switzerland.
Transvaal.
Union of South Africa.
Uruguay.
Western Australia.

As will be noted, there are at present 32 countries with which the immediate exchange is conducted, no additions having been made during the year.

LIST OF BUREAUS OR AGENCIES THROUGH WHICH EXCHANGES ARE TRANSMITTED.

The following is a list of the bureaus or agencies through which exchanges are transmitted:

ALGERIA, *via* France.
ANGOLA, *via* Portugal.
ARGENTINA: Comisión Protectora de Bibliotecas Populares, Reconquista 538, Buenos Aires.
AUSTRIA: K. K. Statistische Zentral-Kommission, Vienna.
AZORES, *via* Portugal.
BELGIUM: Service Belge des Échanges Internationaux, Rue des Longs-Chariots 46, Brussels.
BOLIVIA: Oficina Nacional de Estadística, La Paz.
BRAZIL: Serviço de Permutações Internacionaes, Bibliotheca Nacional, Rio de Janeiro.
BRITISH COLONIES: Crown Agents for the Colonies, London.[1]
BRITISH GUIANA: Royal Agricultural and Commercial Society, Georgetown.
BRITISH HONDURAS: Colonial Secretary, Belize.
BULGARIA: Institutions Scientifiques de S. M. le Roi de Bulgarie, Sofia.
CANARY ISLANDS, *via* Spain.
CHILE: Servicio de Canjes Internacionales, Biblioteca Nacional, Santiago.
CHINA: American-Chinese Publication Exchange Department, Shanghai Bureau of Foreign Affairs, Shanghai.
COLOMBIA: Oficina de Canjes Internacionales y Reparto, Biblioteca Nacional, Bogota.

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[1] This method is employed for communicating with several of the British colonies with which no medium is available for forwarding exchanges direct.

COSTA RICA: Oficina de Depósito y Canje Internacional de Publicaciones, San José.

DENMARK: Kongelige Danske Videnskabernes Selskab, Copenhagen.

DUTCH GUIANA: Surinaamsche Koloniale Bibliotheek, Paramaribo.

ECUADOR: Ministerio de Relaciones Exteriores, Quito.

EGYPT: Government Publications Office, Printing Department, Cairo.

FRANCE: Service Français des Échanges Internationaux, 110 Rue de Grenelle, Paris.

GERMANY: Amerika-Institut, Berlin, N. W. 7.

GREAT BRITAIN AND IRELAND: Messrs. William Wesley & Son, 28 Essex Street, Strand, London.

GREECE: Bibliothèque Nationale, Athens.

GREENLAND, *via* Denmark.

GUADELOUPE, *via* France.

GUATEMALA: Instituto Nacional de Varones, Guatemala.

GUINEA, *via* Portugal.

HAITI: Secrétaire d'État des Relations Extérieures, Port au Prince.

HONDURAS: Biblioteca Nacional, Tegucigalpa.

HUNGARY: Dr. Julius Pikler, Municipal Office of Statistics, Váci-utca 80, Budapest.

ICELAND, *via* Denmark.

INDIA: India Store Department, India Office, London.

ITALY: Ufficio degli Scambi Internazionali, Biblioteca Nazionale Vittorio Emanuele, Rome.

JAMAICA: Institute of Jamaica, Kingston.

JAPAN: Imperial Library of Japan, Tokyo.

JAVA, *via* Netherlands.

KOREA: His Imperial Japanese Majesty's Residency-General, Seoul.

LIBERIA: Bureau of Exchanges, Department of State, Monrovia.

LOURENÇO MARQUEZ: Government Library, Lourenço Marques.

LUXEMBURG, *via* Germany.

MADAGASCAR, *via* France.

MADEIRA, *via* Portugal.

MONTENEGRO: Ministère des Affaires Étrangères, Cetinje.

MOZAMBIQUE, *via* Portugal.

NETHERLANDS: Bureau Scientifique Central Néerlandais, Bibliothèque de l'Université, Leyden.

NEW GUINEA, *via* Netherlands.

NEW SOUTH WALES: Public Library of New South Wales, Sydney.

NEW ZEALAND: Dominion Museum, Wellington.

NICARAGUA: Ministerio de Relaciones Exteriores, Managua.

NORWAY: Kongelige Norske Frederiks Universitet Bibliotheket, Christiania.

PANAMA: Secretaria de Relaciones Exteriores, Panama.

PARAGUAY: Ministerio de Relaciones Exteriores, Asuncion.

PERSIA: Board of Foreign Missions of the Presbyterian Church, New York City.

PERU: Oficina de Reparto, Depósito y Canje Internacional de Publicaciones, Ministerio de Fomento, Lima.

PORTUGAL: Serviço de Permutações Internacionaes, Bibliotheca Nacional, Lisbon.

QUEENSLAND: Bureau of Exchanges of International Publications, Chief Secretary's Office, Brisbane.

ROUMANIA: Academia Romana, Bucharest.

RUSSIA: Commission Russe des Échanges Internationaux, Bibliothèque Impériale Publique, St. Petersburg.

SALVADOR: Ministerio de Relaciones Exteriores, San Salvador.

SERVIA: Section Administrative du Ministère des Affaires Étrangères, Belgrade.
SIAM: Department of Foreign Affairs, Bangkok.
SOUTH AUSTRALIA: Public Library of South Australia, Adelaide.
SPAIN: Servicio del Cambio Internacional de Publicaciones, Cuerpo Facultativo de Archiveros, Bibliotecarios y Arqueólogos, Madrid.
SUMATRA, *via* Netherlands.
SWEDEN: Kongliga Svenska Vetenskaps Akademien, Stockholm.
SWITZERLAND: Service des Échanges Internationaux, Bibliothèque Fédérale Centrale, Berne.
SYRIA: Board of Foreign Missions of the Presbyterian Church, New York.
TASMANIA: Secretary to the Premier, Hobart.
TRINIDAD: Royal Victoria Institute of Trinidad and Tobago, Port-of-Spain.
TUNIS, *via* France.
TURKEY: American Board of Commissioners for Foreign Missions, Boston.
UNION OF SOUTH AFRICA: Government Printing Works, Pretoria, Transvaal.
URUGUAY: Oficina de Canje Internacional, Montevideo.
VENEZUELA: Biblioteca Nacional, Caracas.
VICTORIA: Public Library of Victoria, Melbourne.
WESTERN AUSTRALIA: Public Library of Western Australia, Perth.
WINDWARD AND LEEWARD ISLANDS: Imperial Department of Agriculture, Bridgetown, Barbados.

It is my sad duty to record here the death on June 25, 1914, of Dr. F. W. True, the Assistant Secretary in charge of Library and Exchanges. Dr. True was in charge of the exchanges a little over three years, having been appointed June 11, 1911. His official connection with the Institution, however, dates from 1881. During his incumbency Dr. True took special steps to increase the efficiency of the Exchange Service. Recently he addressed communications to the chiefs of the various foreign exchange bureaus and establishments acting as distributing agencies, requesting them to furnish him with certain statistical information regarding the exchanges carried on under their supervision for use in connection with the preparation of an article on the present condition of the International Exchange Service throughout the world which he had under way.

Respectfully submitted.

C. W. SHOEMAKER,
Chief Clerk International Exchange Service.

Dr. CHARLES D. WALCOTT,
Secretary of the Smithsonian Institution.

AUGUST 5, 1914.

APPENDIX 4.

REPORT ON THE NATIONAL ZOOLOGICAL PARK.

SIR: I have the honor to submit herewith a report concerning the operations of the National Zoological Park during the fiscal year ending June 30, 1914.

By the sundry civil act approved June 23, 1913, Congress allowed $100,000 for improvement and maintenance. The cost of food for the animals during the year was $23,200, an increase of about $3,000; considerable repairs were required to some of the older buildings, and a large amount of damage on the grounds was done by a heavy storm. The amount remaining available for improvement and expansion therefore was proportionately reduced.

ACCESSIONS.

The most important accessions were a male hippopotamus, a pair of young Bengal tigers, a pair of young lions, a sable antelope, and an American white crane. The animals mentioned in the last annual report as on their way from the Government Zoological Garden at Giza, Egypt, arrived early in the present fiscal year. Among them were a pair of young African elephants and a pair of cheetahs. The total expended for the purchase and transportation of animals was $7,450, which includes $1,900 paid for bringing over the animals from Giza.

Mammals and birds were born and hatched in the park to the number of 95, including bears of four species, an otter, five mink, several monkeys, a llama, a chamois, an Arabian gazelle, various deer, two American white pelicans, and some other mammals and birds.

EXCHANGES.

Comparatively few exchanges were made during the year. Among animals obtained by this means were a leopard, a Japanese bear, a white-tailed gnu, several other mammals, and a few birds and large snakes.

GIFTS.

Miss M. H. Berger, Washington, D. C., an alligator.
Mr. Walter Brown, Washington, D. C., a broad-winged hawk.
Dr. D. E. Buckingham, Washington, D. C., a coyote.

Mrs. Charlotte Buford, Washington, D. C., a red-fronted parrot.
Mrs. M. E. Butler, Washington, D. C., a Belgian hare.
Mr. Walter Campbell, Alexandria, Va., a woodchuck.
Mrs. C. E. Clark, Washington, D. C., a finch.
Mrs. Thomas W. Coskery, Flemingsburg, Ky., a bald eagle.
Mrs. Ida M. Dalton, Washington, D. C., a broad-winged hawk.
Miss Elizabeth Eccleston, Forest Glen, Md., a common ferret.
Lieut. J. H. Everson, United States Navy, a roseate spoonbill.
Mr. W. L. Field, Washington, D. C., a Gila monster.
Capt. S. S. Flower, Giza, Egypt, an Arabian baboon.
Mrs. Elsie Frizzell, Washington, D. C., an American magpie.
Mr. F. P. Hall, Washington, D. C., a muscovy duck.
Mr. Hugh G. Harp, Bluemont, Va., a Cooper's hawk.
Mr. Hendley, Washington, D. C., a brown capuchin.
Mrs. C. B. Hight, Washington, D. C., an alligator.
Miss Barbara Hubbard, Washington, D. C., three common canaries.
Mrs. Hughes, Washington, D. C., a goldfinch.
Mr. C. E. Hunt, Washington, D. C., a cardinal and four doves.
Mrs. Lieber, Philadelphia, Pa., an alligator.
Miss Annie C. Linn, Alexandria, Va., a raccoon.
Asst. Paymaster Stanley Mathes, United States Navy, a paca.
Miss Maria I. McCormack, Washington, D. C., a Cuban parrot.
Mr. E. B. McLean, Washington, D. C., a peafowl.
Mr. Mills, Washington, D. C., a common canary.
Mr. A. M. Nicholson, Orlando, Fla., 12 young water moccasins.
Mr. R. G. Paine, Washington, D. C., a hog-nosed snake.
Mr. W. W. Reese, Ironton, Va., a bittern.
Mr. Peter Simon, Washington, D. C., a hog-nosed snake.
Mr. J. T. Smoot, Smoot, W. Va., a horned owl.
Mr. Andreas Soto, Cape San Antonio, Cuba, two white-headed doves.
Hon. William J. Stone, United States Senate, a raccoon.
Mr. F. A. Thackery, Sacaton, Ariz., a spotted lynx, two Gila monsters, and a horned lizard.
Mr. H. W. Wheeler, Street, Md., a black snake.
Hon. Woodrow Wilson, Washington, D. C., three opossums.
Unknown donor, a pigeon hawk.

LOSSES.

The losses were distributed throughout the collection, the more important being a lion, a cougar, a guanaco, a gazelle, and an Arabian baboon which died from pneumonia; an East African buffalo, a gnu, a mandrill, and a Malay bear from tuberculosis; two lions, a tiger, a moose, and an American bison from gastritis and enteritis; a rhea, a sarus crane, a flamingo, and a great bustard from aspergillosis; and several mammals and birds as the result of fighting and accidents. A number of birds were killed by predatory animals living at large in the park.

Such of the dead animals as were of value for study or for other museum purposes were transferred to the National Museum to the number of 88. Autopsies were made, as usual, by the Pathological

Division of the Bureau of Animal Industry, Department of Agriculture.[1]

ANIMALS IN THE COLLECTION JUNE 30, 1914.

MAMMALS.

Green monkey (*Cercopithecus callitrichus*)	1
Mona monkey (*Cercopithecus mona*)	2
Diana monkey (*Cercopithecus diana*)	1
Sooty mangabey (*Cercocebus fuliginosus*)	1
Bonnet monkey (*Macacus sinicus*)	1
Macaque monkey (*Macacus cynomolgus*)	2
Pig-tailed monkey (*Macacus nemestrinus*)	5
Rhesus monkey (*Macacus rhesus*)	15
Brown macaque (*Macacus arctoides*)	3
Japanese monkey (*Macacus fuscatus*)	8
Black ape (*Cynopithecus niger*)	1
Chacma (*Papio porcarius*)	1
Hamadryas baboon (*Papio hamadryas*)	3
Mandrill (*Papio maimon*)	1
Gray spider monkey (*Ateles geoffroyi*)	1
White-throated capuchin (*Cebus hypoleucus*)	1
Brown monkey (*Cebus fatuellus*)	1
Durukuli (*Nyctipithecus trivirgatus*)	1
Mongoose lemur (*Lemur mongoz*)	1
Ring-tailed lemur (*Lemur catta*)	2
Garnett's galago (*Galago garnetti*)	1
Polar bear (*Thalarctos maritimus*)	2
European brown bear (*Ursus arctos*)	2
Kadiak bear (*Ursus middendorffi*)	1
Yakutat bear (*Ursus dalli*)	1
Alaskan brown bear (*Ursus gyas*)	3
Kidder's bear (*Ursus kidderi*)	2
Himalayan bear (*Ursus thibetanus*)	1
Japanese bear (*Ursus japonicus*)	1
Grizzly bear (*Ursus horribilis*)	3
Black bear (*Ursus americanus*)	9
Cinnamon bear (*Ursus americanus*)	2
Sloth bear (*Melursus ursinus*)	1
Kinkajou (*Cercoleptes caudivolvulus*)	1
Cacomistle (*Bassariscus astuta*)	1
Gray coatimundi (*Nasua narica*)	5
Raccoon (*Procyon lotor*)	10
American badger (*Taxidea taxus*)	3
Common skunk (*Mephitis putida*)	4
American marten (*Mustela americana*)	4
Fisher (*Mustela pennantii*)	1
Mink (*Putorius vison*)	13
Common ferret (*Putorius putorius*)	1
Black-footed ferret (*Putorius nigripes*)	1
North American otter (*Lutra canadensis*)	2
Eskimo dog (*Canis familiaris*)	13
Dingo (*Canis dingo*)	1
Gray wolf (*Canis occidentalis*)	4
Coyote (*Canis latrans*)	4
Woodhouse's coyote (*Canis frustror*)	8
Red fox (*Vulpes pennsylvanicus*)	5
Swift fox (*Vulpes velox*)	2
Arctic fox (*Vulpes lagopus*)	1
Gray fox (*Urocyon cinereo-argenteus*)	5
Spotted hyena (*Hyæna crocuta*)	1
African palm civet (*Viverra civetta*)	1
Common genet (*Genetta genetta*)	2
Cheetah (*Cynailurus jubatus*)	2
Sudan lion (*Felis leo*)	8
Kilimanjaro lion (*Felis leo sabakiensis*)	2
Tiger (*Felis tigris*)	2
Cougar (*Felis oregonensis hippolestes*)	1
Jaguar (*Felis onca*)	1
Leopard (*Felis pardus*)	3
Black leopard (*Felis pardus*)	1
Canada lynx (*Lynx canadensis*)	1
Bay lynx (*Lynx rufus*)	8
Spotted lynx (*Lynx rufus texensis*)	2
Florida lynx (*Lynx rufus floridanus*)	1
Steller's sea lion (*Eumetopias stelleri*)	1
California sea lion (*Zalophus californianus*)	2
Northern fur seal (*Callotaria alascana*)	1
Harbor seal (*Phoca vitulina*)	2
Fox squirrel (*Sciurus niger*)	9
Western fox squirrel (*Sciurus ludovicianus*)	8
Gray squirrel (*Sciurus carolinensis*)	40
Black squirrel (*Sciurus carolinensis*)	20
Albino squirrel (*Sciurus carolinensis*)	1
Prairie dog (*Cynomys ludovicianus*)	54
Albino woodchuck (*Arctomys monax*)	1
Alpine marmot (*Arctomys marmotta*)	1
American beaver (*Castor canadensis*)	6
Hutia-conga (*Capromys pilorides*)	1
Indian porcupine (*Hystrix leucura*)	2
Canada porcupine (*Erethizon dorsatus*)	1
Canada porcupine (*Erethizon dorsatus*) albino	1
Mexican agouti (*Dasyprocta mexicana*)	1
Azara's agouti (*Dasyprocta azaræ*)	2
Crested agouti (*Dasyprocta cristata*)	2
Hairy-rumped agouti (*Dasyprocta prymnolopha*)	2
Paca (*Cœlogenys paca*)	3
Guinea pig (*Cavia cutleri*)	13
Patagonian cavy (*Dolichotis patagonica*)	1
Capybara (*Hydrochœrus capybara*)	1
Domestic rabbit (*Lepus cuniculus*)	15

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[1] The causes of death were reported to be as follows: Enteritis, 23; gastritis, 2; gastroenteritis, 2; pneumonia, 15; pleuropneumonia, 1; congestion of lungs, 2; tuberculosis, 10; aspergillosis, 4; septicemia, 2; congestion of liver, 1; rupture of heart, 1; impaction of gall bladder and ducts, 1; impaction of stomach with stones, 1; tumor, 1; purulent conjunctivitis, 1; cataract, 1; congelation, 1; anemia due to old age, 2; accident, 3; and undetermined, 4.

Animals in the collection June 30, 1914—Continued.

MAMMALS—Continued.

Cape hyrax (*Procavia capensis*)	2
African elephant (*Elephas oxyotis*)	2
Indian elephant (*Elephas maximus*)	1
Brazilian tapir (*Tapirus americanus*)	4
Grevy's zebra (*Equus grevyi*)	2
Zebra-horse hybrid (*Equus grevyi-caballus*)	1
Zebra-donkey hybrid (*Equus grevyi-asinus*)	1
Grant's zebra (*Equus burchelli granti*)	1
Collared peccary (*Dicotyles angulatus*)	8
Wild boar (*Sus scrofa*)	1
Northern wart hog (*Phacochœrus africanus*)	2
Hippopotamus (*Hippopotamus amphibius*)	2
Guanaco (*Lama huanachus*)	2
Llama (*Lama glama*)	7
Alpaca (*Lama pacos*)	3
Vicugna (*Lama vicugna*)	2
Bactrian camel (*Camelus bactrianus*)	2
Arabian camel (*Camelus dromedarius*)	3
Sambar deer (*Cervus aristotelis*)	3
Philippine deer (*Cervus philippinus*)	1
Hog deer (*Cervus porcinus*)	7
Barasingha deer (*Cervus duvaucelii*)	12
Axis deer (*Cervus axis*)	8
Japanese deer (*Cervus sika*)	19
Red deer (*Cervus elaphus*)	7
American elk (*Cervus canadensis*)	8
Fallow deer (*Cervus dama*)	4
Virginia deer (*Odocoileus virginianus*)	11
Mule deer (*Odocoileus hemionus*)	1
Columbian black-tailed deer (*Odocoileus columbianus*)	1
Cuban deer (*Odocoileus* sp.)	1

Prong-horn antelope (*Antilocapra americana*)	2
Coke's hartebeest (*Bubalis cokei*)	1
Blessbok (*Damaliscus albifrons*)	1
White-tailed gnu (*Connochætes gnu*)	1
Defassa water buck (*Cobus defassa*)	1
Indian Antelope (*Antilope cervicapra*)	3
Dorcas gazelle (*Gazella dorcas*)	1
Arabian gazelle (*Gazella arabica*)	4
Sable antelope (*Hippotragus niger*)	1
Nilgai (*Boselaphus tragocamelus*)	3
Congo harnessed antelope (*Tragelaphus gratus*)	2
Chamois (*Rupicapra tragus*)	3
Tahr (*Hemitragus jemlaicus*)	4
Common goat (*Capra hircus*)	6
Angora goat (*Capra hircus*)	2
Circassian goat (*Capra hircus*)	4
Barbary sheep (*Ovis tragelaphus*)	12
Barbados sheep (*Ovis aries-tragelaphus*)	10
Anoa (*Anoa depressicornis*)	1
Zebu (*Bibos indicus*)	3
Yak (*Poëphagus grunniens*)	5
American bison (*Bison americanus*)	16
Hairy armadillo (*Dasypus villosus*)	3
Wallaroo (*Macropus robustus*)	3
Red kangaroo (*Macropus rufus*)	2
Red-necked wallaby (*Macropus ruficollis*)	1
Virginia opossum (*Didelphys marsupialis*)	1
Virginia opossum (*Didelphys marsupialis*) albino	1
Common wombat (*Phascolomys mitchelli*)	1

BIRDS.

Catbird (*Dumetella carolinensis*)	2
Brown thrasher (*Toxostoma rufum*)	1
Japanese robin (*Liothrix luteus*)	7
Laughing thrush (*Garrulax leucolophus*)	2
Bishop finch (*Tanagra episcopus*)	4
Cut-throat finch (*Amadina fasciata*)	8
Zebra finch (*Amadina castanotis*)	4
Black-headed finch (*Munia atricapilla*)	6
Three-colored finch (*Munia malacca*)	6
White-headed finch (*Munia maja*)	9
Nutmeg finch (*Munia punctularia*)	6
Java sparrow (*Munia oryzivora*)	13
White Java sparrow (*Munia oryzivora*)	12
Sharp-tailed grass finch (*Poëphila acuticauda*)	1
Silver-bill finch (*Aidemosyne cantans*)	4
Chestnut-breasted finch (*Donacola castaneothorax*)	6
Napolean weaver (*Pyromelana afra*)	4
Madagascar weaver (*Foudia madagascariensis*)	4
Red-billed weaver (*Quelea quelea*)	8

Whydah weaver (*Vidua paradisea*)	27
Red-crested cardinal (*Paroaria cucullata*)	8
Rose-breasted grosbeak (*Zamelodia ludoviciana*)	1
Common cardinal (*Cardinalis cardinalis*)	2
Siskin (*Spinus spinus*)	5
Saffron finch (*Sycalis flaveola*)	19
Yellow-hammer (*Emberiza citrinella*)	1
Common canary (*Serinus canarius*)	26
Linnet (*Linota cannabina*)	4
Cowbird (*Molothrus ater*)	1
Meadow lark (*Sturnella magna*)	2
Glossy starling (*Lamprotornis caudatus*)	1
Malabar mynah (*Poliopsar malabaricus*)	2
European raven (*Corvus corax*)	1
American raven (*Corvus corax sinuatus*)	2
Common crow (*Corvus brachyrhynchos*)	1
Green jay (*Xanthoura luxuosa*)	1
White-throated jay (*Garrulus leucotis*)	2

Animals in the collection June 30, 1914—Continued.

BIRDS—Continued.

Blue jay (*Cyanocitta cristata*)	3
American magpie (*Pica pica hudsonica*)	3
Red-billed magpie (*Urocissa occipitalis*)	2
Piping crow (*Gymnorhina tibicen*)	1
Giant kingfisher (*Dacelo gigas*)	3
Sulphur-crested cockatoo (*Cacatua galerita*)	3
White cockatoo (*Cacatua alba*)	6
Leadbeater's cockatoo (*Cacatua leadbeateri*)	1
Bare-eyed cockatoo (*Cacatua gymnopis*)	4
Roseate cockatoo (*Cacatua roseicapilla*)	12
Cockateel (*Calopsittacus novæ-hollandiæ*)	2
Yellow and blue macaw (*Ara ararauna*)	2
Red and yellow and blue macaw (*Ara macao*)	6
Red and blue macaw (*Ara chloroptera*)	2
Great green macaw (*Ara militaris*)	1
Mexican conure (*Conurus holochlorus*)	1
Gray-breasted parrakeet (*Myopsittacus monachus*)	3
Cuban parrot (*Amazona leucocephala*)	3
Orange-winged amazon (*Amazona amazonica*)	1
Festive amazon (*Amazona festiva*)	1
Porto Rican amazon (*Amazona vittata*)	1
Yellow-shouldered amazon (*Amazona ochroptera*)	2
Yellow-fronted amazon (*Amazona ochrocephala*)	2
Red-fronted amazon (*Amazona rhodocorytha*)	1
Yellow-headed amazon (*Amazona levaillanti*)	2
Blue-fronted amazon (*Amazona æstiva*)	2
Lesser vasa parrot (*Coracopsis nigra*)	2
Banded parrakeet (*Palæornis fasciata*)	1
Alexandrine parrakeet (*Palæornis alexandri*)	2
Love bird (*Agapornis pullaria*)	1
Green parrakeet (*Loriculus* sp.)	2
Shell parrakeet (*Melopsittacus undulatus*)	4
Great horned owl (*Bubo virginianus*)	11
Arctic horned owl (*Bubo virginianus subarcticus*)	1
Screech owl (*Otus asio*)	3
Barred owl (*Strix varia*)	2
Barn owl (*Aluco pratincola*)	1
Sparrow hawk (*Falco sparverius*)	1
Bald eagle (*Haliæetus leucocephalus*)	8
Alaskan bald eagle (*Haliæetus leucocephalus alascanus*)	1
Golden eagle (*Aquila chrysaëtos*)	4
Harpy eagle (*Thrasaëtus harpyia*)	1
Chilian eagle (*Geranoaëtus melanoleucus*)	1
Crowned hawk eagle (*Spizaëtus coronatus*)	1
Broad-winged hawk (*Buteo platypterus*)	1
Swainson's hawk (*Buteo swainsoni*)	1
Venezuelan hawk	1
Caracara (*Polyborus cheriway*)	3
Lammergeyer (*Gypaëtus barbatus*)	1
South American condor (*Sarcorhamphus gryphus*)	1
California condor (*Gymnogyps californianus*)	3
Griffon vulture (*Gyps fulvus*)	2
Cinereous vulture (*Vultur monachus*)	2
Egyptian vulture (*Neophron percnopterus*)	1
Turkey vulture (*Cathartes aura*)	4
Black vulture (*Catharista urubu*)	2
King vulture (*Gypagus papa*)	2
Red-billed pigeon (*Columba flavirostris*)	4
White-crowned pigeon (*Columba leucocephala*)	2
Band-tailed pigeon (*Columba fasciata*)	4
Mourning dove (*Zenaidura macroura*)	7
Peaceful dove (*Geopelia tranquilla*)	2
Collared turtle dove (*Turtur risorius*)	13
Cape masked dove (*Œna capensis*)	5
Nicobar pigeon (*Calœnas nicobarica*)	2
Barred curassow (*Crax fasciolata*)	1
Wild turkey (*Meleagris gallopavo silvestris*)	8
Peafowl (*Pavo cristata*)	80
Jungle fowl (*Gallus bankiva*)	1
English pheasant (*Phasianus colchicus*)	1
European quail (*Coturnix communis*)	1
Massena quail (*Cyrtonyx montezumæ*)	4
Black-backed gallinule (*Porphyrio melanotus*)	1
American coot (*Fulica americana*)	5
Flightless rail (*Ocydromus australis*)	1
Great bustard (*Otis tarda*)	1
Common cariama (*Cariama cristata*)	1
Demoiselle crane (*Anthropoides virgo*)	6
Crowned crane (*Balearica pavonina*)	2
Whooping crane (*Grus americana*)	1
Sandhill crane (*Grus mexicana*)	2
Australian crane (*Grus australasiana*)	1
European crane (*Grus cinerea*)	1
Indian white crane (*Grus leucogeranus*)	2
Ruff (*Machetes pugnax*)	2
Black-crowned night heron (*Nycticorax nycticorax nævius*)	8
Snowy egret (*Egretta candidissima*)	3
Great white heron (*Herodias egretta*)	1
Great blue heron (*Ardea herodias*)	3
Great black-crowned heron (*Ardea cocoi*)	1
Boat-bill (*Cancroma cochlearia*)	2

Animals in the collection June 30, 1914—Continued.

BIRDS—Continued.

Black stork (*Ciconia nigra*)	1
Marabou stork (*Leptoptilus dubius*)	1
Wood ibis (*Mycteria americana*)	2
Sacred ibis (*Ibis æthiopica*)	3
White ibis (*Guara alba*)	18
Roseate spoonbill (*Ajaja ajaja*)	2
European flamingo (*Phœnicopterus roseus*)	5
Whistling swan (*Olor columbianus*)	5
Mute swan (*Cygnus gibbus*)	7
Black swan (*Chenopis atrata*)	1
Muscovy duck (*Cairina moschata*)	2
White muscovy duck (*Cairina moschata*)	2
Wandering tree-duck (*Dendrocygna arcuata*)	6
Fulvous tree-duck (*Dendrocygna bicolor*)	2
Brant (*Branta bernicla glaucogastra*)	1
Canada goose (*Branta canadensis*)	7
Hutchins's goose. (*Branta canadensis hutchinsii*)	3
Lesser snow goose (*Chen hyperboreus*)	1
Greater snow goose (*Chen hyperboreus nivalis*)	1
American white-fronted goose (*Anser albifrons gambeli*)	1
Chinese goose (*Anser cygnoides*)	8
Scaup duck (*Marila marila*)	5
Red-headed duck (*Marila americana*)	2
Wood duck (*Aix sponsa*)	5
Mandarin duck (*Dendronessa galericulata*)	5
Pintail (*Dafila acuta*)	4
Shoveler duck (*Spatula clypeata*)	1
Black duck (*Anas rubripes*)	3
Mallard (*Anas platyrhynchos*)	13
American white pelican (*Pelecanus erythrorhynchos*)	9
European white pelican (*Pelecanus onocrotalus*)	1
Roseate pelican (*Pelecanus roseus*)	1
Brown pelican (*Pelecanus occidentalis*)	5
Australian pelican (*Pelecanus conspicillatus*)	2
Florida cormorant (*Phalacrocorax auritus floridanus*)	13
Mexican cormorant (*Phalacrocorax vigua mexicanus*)	1
Water turkey (*Anhinga anhinga*)	2
American herring gull (*Larus argentatus smithsonianus*)	3
Laughing gull (*Larus atricilla*)	2
South African ostrich (*Struthio australis*)	7
Somali ostrich (*Struthio molybdophanes*)	1
Common cassowary (*Casuarius galeatus*)	1
Common rhea (*Rhea americana*)	2
Emu (*Dromæus novæ hollandiæ*)	2

REPTILES.

Alligator (*Alligator mississippiensis*)	20
Painted box-tortoise (*Cistudo ornata*)	2
Duncan Island tortoise (*Testudo ephippium*)	2
Albemarle Island tortoise (*Testudo vicina*)	1
Horned lizard (*Phrynosoma cornutum*)	1
Gila monster (*Heloderma suspectum*)	4
Regal python (*Python reticulatus*)	4
Common boa (*Boa constrictor*)	2
Anaconda (*Eunectes murinus*)	1
Velvet snake (*Epicrates cenchris*)	3
Spreading adder (*Heterodon platyrhinus*)	1
Black snake (*Zamenis constrictor*)	1
Water snake (*Natrix sipedon*)	3
Common garter snake (*Eutænia sirtalis*)	1
Water moccasin (*Ancistrodon piscivorus*)	9
Copperhead (*Ancistrodon contortrix*)	1
Diamond rattlesnake (*Crotalus adamanteus*)	4
Banded rattlesnake (*Crotalus horridus*)	1

STATEMENT OF THE COLLECTION.

ACCESSIONS DURING THE YEAR.

Presented	59
Purchased	120
Born and hatched in the National Zoological Park	95
Received in exchange	17
Deposited in National Zoological Park	30
Captured in National Zoological Park	4
Total	325

SUMMARY.

Animals on hand July 1, 1913	1,468
Accessions during the year	325
	1,793
Deduct loss (by exchange, death, return of animals, etc.)	431
On hand June 30, 1914	1,362

Class.	Species.	Individuals.
Mammals	150	604
Birds	172	697
Reptiles	18	61
Total	340	1,362

The number of animals on hand at the close of this year was about 100 less than the previous year. This decrease occurred mainly in small birds, conditions in the temporary bird house being so unsatisfactory that it seemed advisable to reduce somewhat that part of the collection. The floor of the bird house had to be renewed and the underpinning replaced and made rat proof.

Fewer reptiles, also, were on hand, as a part of the space previously used for them in the lion house was required for the new hippopotamus.

VISITORS.

The number of visitors to the park during the year, as determined by count and estimate, was 733,277, a daily average of 2,009. This was about 100,000 more than during the previous fiscal year. The largest number in any one month was 142,491, in April, 1914. The largest number during one day was 56,981, on April 13 (Easter Monday). Vehicles were excluded from 10 a. m. to 5 p. m. of that day because of the crowded condition of the roads.

Seventy-nine schools, classes, etc., visited the park, with a total of 3,172 individuals.

IMPROVEMENTS.

The amount remaining from the appropriation, after providing for maintenance and the acquisition of animals already mentioned, was used for such minor improvements as were most urgently needed. The fitting up of the old elephant barn as temporary quarters for the pair of African elephants was completed, and a good-sized yard built in connection with it, inclosed by a strong steel fence. The yard includes a bathing pool. The adjoining inclosure and pool for tapirs were completed and put in use early in the year.

New hippopotamus quarters were arranged in the lion house by enlarging the cage formerly occupied by elephant seals. This was already provided with a tank of sufficient size, and, by extending the exterior wall, ample floor space was secured. The female hippopotamus, which had outgrown her temporary quarters, was transferred to the new and much larger cage, and the cage vacated was used for a young male that had been obtained at an unusually favorable price. Both animals have access to the outdoor yard and the large pool which it contains. A new inclosure and shelter house for Arabian camels were built near the sheep and deer inclosures and two new yards were added to the series for wolves and foxes.

A yard 40 by 56 feet, with 10 breeding pens inclosed in it, was built to provide for the breeding and study of mink in cooperation with the Department of Agriculture.

During several years predatory animals living at large in the park had at times forced their way into the flying cage and caused considerable loss among the birds. In order to prevent this the guardrail about the cage was rebuilt, using between the posts a wire netting with small mesh and at the top a sheet-iron hood. This has proved to be effective against both rats and larger vermin.

A small temporary toilet for men was built near the entrance from Adams Mill Road.

A hot-water heating plant was installed in the office building, which had up to that time been heated, rather unsatisfactorily, with stoves. At the same time new floors were laid on the main floor of the office and some other much-needed repairs made. In order to provide for more convenient and economical use of the machines in the workshop, two additional electric motors were installed there.

The drinking fountains with attached cups were removed and seven "bubble" fountains set in their places. Several of these are fitted with faucets for the accommodation of visitors who bring cups or desire to obtain water for picnic purposes.

Two tennis courts were constructed in the lower end of the park where there is level ground that is not as yet available for other purposes.

The cost of these improvements was as follows:

Fitting up old elephant barn and building yard	$1,325
Completing yard and pool for tapirs	300
New hippopotamus quarters	650
Inclosure and shelter house for Arabian camels	390
Additional yards for wolves	400
Quarters for breeding mink	325
New guard rail, with foundation wall, at flying cage	750
Small toilet house for men	200
Heating plant and new floors in office building	950
Additional motors in workshop	350
"Bubble" drinking fountains	200
Two tennis courts	150

MAINTENANCE OF BUILDINGS, INCLOSURES, GROUNDS, ETC.

Considerable repairs had to be made to some of the buildings and inclosures, including new roof covering on part of the lion house and the rebuilding of the fence around the elk paddock, and a portion of the retaining wall above the bear yards on the eastern side of the park was rebuilt where it had been undermined by the weathering of the rock below.

A severe storm on July 30, 1913, destroyed a number of large trees and caused serious damage throughout the park. The cost of removing the débris and restoring the park to its normal condition was about $1,500.

BRIDGE.

The construction of the "rough stone or bowlder bridge" across Rock Creek, which was mentioned in the last annual report, proceeded in a satisfactory manner. The contract for the excavation and masonry work was secured by the lowest bidder, the Warren F. Brenizer Co. The plans and specifications were prepared by David E. McComb, engineer of bridges, District of Columbia, and it was thought best that the supervising engineer and the inspector of the work should be persons recommended by him. Mr. W. A. Draper was accordingly employed as engineer and Mr. William Champion as inspector. No obstacles of any importance were met with during the progress of the work, though it was found that the excavation required for the piers was somewhat greater than had been anticipated. The bridge was opened for travel on November 1, 1913. As there was a heavy fill of earth over the stone masonry, it was necessary to defer the construction of the macadam surface and concrete sidewalk until spring. This also was satisfactorily completed during June, 1914.

The following is a statement of the expenditures from the appropriation of $20,000:

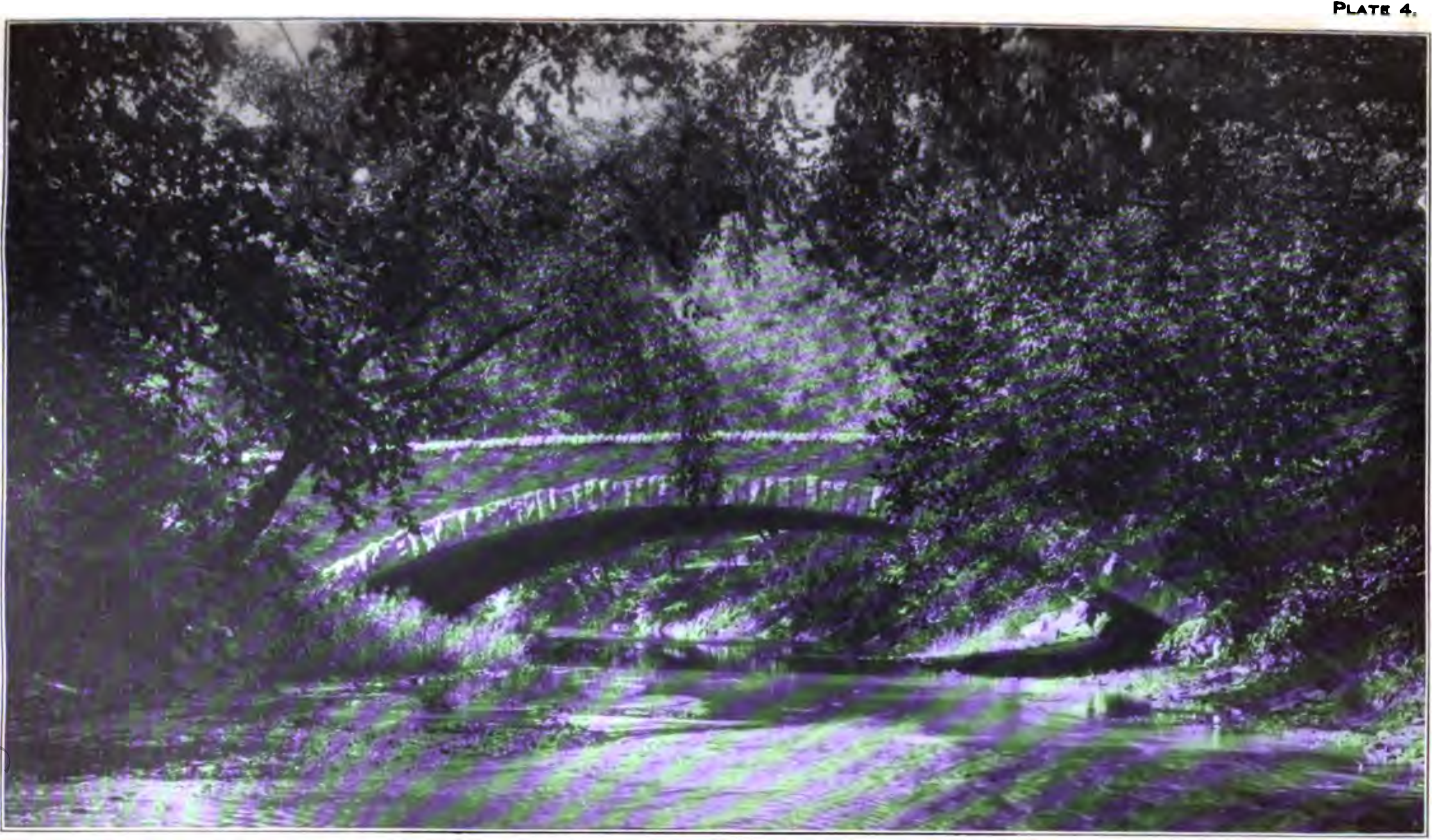
Expenditures prior to July 1, 1913 (all outside of contract for excavation and masonry)	$1,776
Total payments under contract	10,914
Expenditures during this fiscal year (outside of contract)	5,158
	17,848

Since the close of the fiscal year expenditures and liabilities have been incurred, amounting to $335, for restoring and perfecting the approaches to the bridge. The total expenditures to date are therefore $18,183.

ALTERATION OF THE WEST BOUNDARY OF THE PARK.

The sundry civil act for the fiscal year ending June 30, 1914, contained the following item:

Readjustment of boundaries: For acquiring, by condemnation, all the lots, pieces, or parcels of land, other than the one hereinafter excepted, that lie



NEW BRIDGE ACROSS ROCK CREEK, NATIONAL ZOOLOGICAL PARK.

between the present western boundary of the National Zoological Park and Connecticut Avenue from Cathedral Avenue to Klingle Road, $107,200, or such portion thereof as may be necessary, said land when acquired, together with the included highways, to be added to and become a part of the National Zoological Park. The proceedings for the condemnation of said land shall be instituted by the Secretary of the Treasury under and in accordance with the terms and provisions of subchapter 1 of chapter 15 of the Code of Law for the District of Columbia.

Under the sanction given by this act the attention of the Secretary of the Treasury was immediately called to the matter. A great delay has occurred. It is understood that a new survey of the property involved was necessary, that the searching of titles to the various parcels of land consumed considerable time. The case is now before the Supreme Court of the District of Columbia awaiting the award of a jury. In the meantime the principal property owner has endeavored to enhance the value of the land by grading and otherwise improving it. The total amount to be purchased is about 10⅓ acres.

ROCK CREEK MAIN INTERCEPTOR.

The District of Columbia having obtained from Congress authority to construct a large sewer, called the "Rock Creek main interceptor," extending from P Street northwest to the Military Road, District of Columbia, began work upon it within the limits of the park on June 1, 1913. The project involves both an open-cut sewer and a tunnel, about 2,000 feet in length, extending from a short distance below the new bridge to the Klingle Road. This construction necessarily produces a considerable disturbance of the surface and defacement of the natural features of the park. This is particularly the case at either end of the tunnel, where thousands of yards of excavated material have been dumped. It is hoped that the District officials will be able to remedy this in some measure when the work shall be completed. This is expected about September 5, 1914.

NEW APPROACH TO THE PARK.

By an act of Congress approved March 2, 1911, there was authorized a new approach to the park from Sixteenth Street and Columbia Road to what has been known as the Quarry Road entrance. This has now been completed by the District with a fine macadam roadway, and offers a most convenient and attractive route for reaching the park from the city. The Quarry Road, which had a very steep and dangerous gradient, has been abolished as a means of access.

IMPORTANT NEEDS.

Aviary.—Attention has been called for several years past to the importance of erecting a suitable house for the care and preservation of the birds of the collection, most of which are now housed in a low, wooden, temporary structure which is by no means suitable for the purpose and has to be constantly renewed by repairs. The matter has been repeatedly urged upon Congress and an appropriation of $80,000 asked for a new structure. This is by no means an extravagant sum, as the aviaries of most zoological collections cost considerably more than this.

Reptile house.—The park has never had an adequate exhibition of the interesting and varied domain of reptiles. A few alligators, some Galapagos tortoises, boas, anacondas, and a few native species are kept in the lion house in quarters which are entirely unsuitable for their proper exhibition and comfort. It is thought that a proper reptile house, where the specimens could be kept in approximately natural conditions, could be built for about $50,000.

Pachyderm house.—There are now in the collection a considerable number of pachydermata or thick-skinned animals, including an Indian elephant, two African elephants, two hippopotami, and four tapirs. These all require special treatment in the way of bathing pools, strong walls, etc. These animals are at present nearly all housed in quarters that are too small and weak. Some of them are young and rapidly growing and it will soon be a difficult matter to confine them. It is also likely that other species will be added to those now on hand. To properly exhibit and care for them a new house should be built. It is thought that this can be done at a cost of $100,000, which is much less than similar structures have cost in other cities.

Hospital and laboratory.—The park has not at the present time any means for properly isolating and caring for the animals that may be injured or ailing. Sick animals are ordinarily exposed to the gaze of the public, to the detriment of the animals and the reputation of the park. Quiet and repose are as necessary to animals as to man, and that can not be assured under the present conditions.

Besides this, which seems required merely from humanitarian reasons, consideration should be given to certain scientific aspects of the matter. The diseases and parasites of animals are but imperfectly understood, and investigations of them are important, both directly and for their analogy with those of man and their possible transmission to the human race. The animals received at the park have usually been kept in insanitary quarters and frequently bring in the germs of disease which they transmit to others. If a strict quarantine for a suitable time could be established, this danger could be avoided in a great measure and the death rate reduced. Further than this there is now no adequate utilization of the animals for scientific purposes.

In other countries the most significant scientific function of collections of living animals has been the advancement of our knowledge with regard to the structure, habits, and activities of animals. Most of the knowledge which has been acquired with regard to the structure of animals has been gained from zoological collections of precisely similar character to those which we have in the National Zoological Park.

I may note, for example, that in the Jardin des Plantes, at Paris, investigations have been carried on since the middle of the eighteenth century by men who are among the most famous scientists that have ever lived. I will mention, among others, Duverney, Daubenton, Buffon, Cuvier, Geoffroy Saint-Hilaire, and Milne-Edwards. In the same way great names are associated with the Zoological Society of London. I may mention in this connection the names of Owen, Flower, Huxley, Sclater, and the present prosector, Beddard. The garden at Berlin has been noted for the work of Hartmann, and in the garden at Amsterdam Fürbringer brought to a conclusion his monumental work upon the structure of birds. I mention a few names among many. It would be easy to extend the list very considerably.

In order to properly utilize the material that comes to the park from the death of the animals, it would be necessary to establish an anatomical and pathological laboratory. This would, of course, involve a considerable expenditure, but I am of the opinion that it would be a wise thing for the Smithsonian Institution to consider the question and to arrange to have the park advance along that line of growth. A proper structure for the purposes above mentioned suitably fitted with the necessary simple apparatus would probably cost $15,000.

Lunch and rest house.—The visiting public is by no means properly served at present in the park, which is rather remote from restaurants or other places where food can be obtained, yet so extensive that a proper view of the collection occupies at least half a day. Very many visitors would be greatly benefited if there were a properly equipped lunch stand where food could be purchased at reasonable prices. This is so generally understood in other places that the lack of such facilities in the park is always a matter of surprise. There is at present only a very inadequate counter, kept on an exposed pavilion, which has to be closed up whenever the weather is inclement. Besides this, persons are not infrequently taken ill or become fatigued while at the park, and there should be means for meeting such emergencies. It is thought that a suitable structure for this purpose, containing the necessary cooking range, rest rooms, and water-closets, can be built for $15,000.

Fill across valley, Ontario Road.—The administration has been considerably embarrassed by the great quantity of earth and débris that is washed down into the park from Ontario Road after every heavy rain. The Commissioners of the District were authorized to extend Adams Mill Road across a deep valley at the foot of Ontario Road, and this has made necessary a very heavy fill of loose earth that is readily excavated by rains. Attempts have been made to arrest this flow, which amounts to many tons of earth, but the means at the disposal of the park are inadequate.

Additions to the collection.—The park is greatly in need of certain well-known animals to make its exhibit more complete. I do not refer to those which are excessively rare, but to those that are common objects of interest to the public. The anthropoid apes, including the gorilla, the orang, the chimpanzee, and the gibbon, should be shown; also the rhinoceros, the East Indian tapir, the giraffe, the eland, the Beisa antelope, the koodoo, the East African buffalo, and a series of mountain goats and sheep, including those from the Western States.

Respectfully submitted.

FRANK BAKER, *Superintendent.*

DR. CHARLES D. WALCOTT,
Secretary of the Smithsonian Institution.

APPENDIX 5.

REPORT ON THE ASTROPHYSICAL OBSERVATORY.

SIR: I have the honor to present the following report on the operations of the Smithsonian Astrophysical Observatory for the year ending June 30, 1914:

EQUIPMENT.

The equipment of the Observatory is as follows:

(*a*) At Washington there is an inclosure of about 16,000 square feet, containing five small frame buildings used for observing and computing purposes, three movable frame shelters covering several out-of-door pieces of apparatus, and also one small brick building containing a storage battery and electrical distribution apparatus.

(*b*) At Mount Wilson, Cal., upon a leased plot of ground 100 feet square, in horizontal projection, are located a one-story cement observing structure, designed especially for solar-constant measurements, and also a little frame cottage, 21 feet by 25 feet, for observer's quarters.

Upon the observing shelter at Mount Wilson there is a tower 40 feet high above the 12-foot piers which had been prepared in the original construction of the building. This tower has been equipped with an improvised tower telescope for use when observing (with the spectrobolometer) the distribution of radiation over the sun's disk.

During the year apparatus for research has been purchased or constructed at the Observatory shop. The value of these additions to the instrumental equipment, not counting the tower above mentioned and its equipment, is estimated at $1,500.

WORK OF THE OBSERVATORY.

AT WASHINGTON.

Observations.—Mr. Fowle has continued the difficult research on the transmission through moist air of radiations of great wave length, such, for instance, as those which bodies at the temperature of the earth emit most freely. He uses a very powerful lamp made up of a large number of Nernst electric glowers, and examines by the aid of the spectrobolometer the energy spectrum of the rays emitted by this lamp, first directly, and then, after the rays have traversed twice or four times a tube 200 feet long, containing air of measured humidity. During the past year Mr. Fowle has been dealing principally with rays of the very longest wave lengths of the terrestrial energy spectrum which moist air transmits. He has reached a wave length of about eighteen microns, which is about twenty-five times the longest wave length visible to the eye, and about three and one-half times the wave length of the solar rays investigated by this Observatory in the years 1890 to 1900.

A great number of difficulties are met with. In the first place, great sensitiveness of the bolometer is required, owing to the feebleness of these rays. Attempts to use a vacuum bolometer have consumed much time, but not yet with entire success. Full success in this seems now probable. In the second place there is great difficulty in determining the amount of radiation lost in the optical train required to reflect the beam to and fro through the long tube. A principal difficulty in this matter arises from the fact that the lamp and its surroundings are unequally hot at different parts, for this has led to different degrees of loss at different wave lengths. This last source of error is so obscure that it escaped our attention for a long time and has required the observations to be repeated after results worthy of publication had, as it was thought, been reached. These and a host of other difficulties have delayed the research, but great hope is now felt that satisfactory results will be ready for publication in another year.

Computations.—The reductions of Mount Wilson and Washington observations take a large part of the time of Mr. Fowle and Mr. Aldrich, as well as the entire time of Miss Graves and a portion of that of Mr. Carrington. This work is nearly up to date.

Mr. Fowle has continued the study of the effect of terrestrial water vapor on the Mount Wilson solar observations and has published several valuable papers upon it. An interesting result is, that after determining and correcting for the effect of atmospheric water vapor on the transmission of solar rays the coefficients of atmospheric transparency determined at Mount Wilson when combined with the barometric pressure after the manner indicated by Lord Rayleigh's theory of gaseous scattering of light, yield the value 2.70 billion billion as the number of molecules at standard pressure and temperature in a cubic centimeter of gas. Prof. Millikan, by a wholly independent kind of reasoning, has derived from electrical experiments the value 2.705 billion billion. The close agreement found is a strong confirmation of the accuracy of our determinations of atmospheric transparency, and accordingly tends to increase confidence in our determination of the solar constant of radiation.

PREPARATION OF APPARATUS.

Sky radiation instruments.—The director and Mr. Aldrich have devoted much time to the design and testing of apparatus for measuring the scattered radiation of the sky by day. What is desired is an instrument exposing horizontally an absorber of radiation in such a manner that the rays of the entire visible hemisphere of the sky would be received upon it, all rays not of solar origin would be excluded by a suitable screen, and the total energy of the scattered sky radiation originally emitted by the sun would be measured accurately. This is a more difficult problem than the measurement of the direct solar radiation, and it is unlikely that quite as high precision can be attained with the sky radiation instrument as with the pyrheliometers used for measuring direct solar radiation. From experiments with several instruments of the kind which have been constructed in the Observatory shop by Mr. Kramer and tested by Messrs. Abbot and Aldrich it now seems probable that the sources of error can be so far eliminated that sky radiation measurements accurate to about 2 per cent will be made. An instrument embodying what are thought to be the final improvements of design is now under construction, and it is hoped it will be used a great deal in the coming year.

Balloon pyrheliometers.—Still more time has been devoted by Messrs. Abbot, Aldrich, and Kramer to the reconstruction and testing of balloon pyrheliometers. Mention was made in last year's report of the proposed measurements of solar radiation by apparatus attached to sounding balloons and raised to great elevations. As stated below, the first trials in August, 1913, while unexpectedly successful in many ways, did not enable us to obtain measurements above the elevation of about 14,000 meters, or 45,000 feet. At this elevation the mercury froze in the thermometers. Also, the clockwork proved not sufficiently accurate for best results. Still the results obtained were so promising that it was thought well to repeat the experiments.

Accordingly the five balloon pyrheliometers were reconstructed. Excellent French clocks were substituted for those used in 1913, and many improvements of the instruments were introduced. Two devices were employed to prevent the freezing of the mercury in the thermometer. In some instruments water jackets, having numerous interior copper bars to act as heat conductors, were arranged. In these it was hoped to make available the latent heat of freezing of the water and thus to prevent the surroundings of the pyrheliometric apparatus from descending far below the freezing point of water. In other instruments electrical temperature regulators were provided. Many experiments were tried to obtain a constant, powerful, and very light electric battery for this purpose. At length a modification of the Roberts cell was designed, in which individual cells weighing 20 grams (¾ ounce) would furnish a constant potential of 1.3 volts and yield a nearly constant current of about 0.5 ampere for nearly two hours. The internal resistance of the cells was only about 0.3 ohms. Barometric elements were made to record on the same drum that recorded radiation. One instrument was constructed to be sent up at night, so as to show if any unexpected phenomena occurred when the instruments were being raised, apart from those due to the sun. Many tests of the instruments were made at different temperatures and pressures, and while immersed in descending air currents comparable to those anticipated to attend the flights. The accompanying illustration shows one of the balloon pyrheliometers as reconstructed.

Silver-disk pyrheliometers.—As in former years, a number of silver-disk pyrheliometers were standardized at the Observatory and sent out by the Institution to several foreign Government observatories.

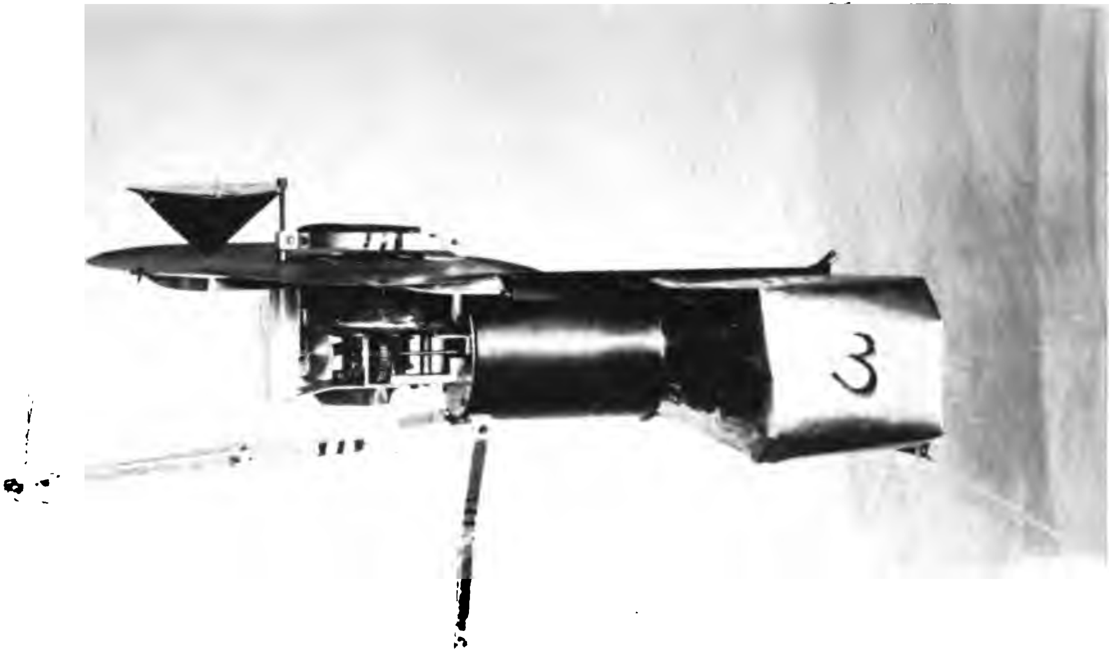
IN THE FIELD.

MOUNT WILSON EXPEDITION OF 1913.

Mr. Aldrich went to Mount Wilson early in July, 1913, and carried on there solar constant measurements until September when he was joined and then relieved by Mr. Abbot, who continued the observations until November. An expedition at the charge of the private funds of the Smithsonian, and under the direction of Mr. A. K. Ångström, was in California during July and August for the purpose of measuring nocturnal radiation at different altitudes, ranging from below sea level to the summit of Mount Whitney, 4,420 meters (14,502 feet). Mr. Aldrich cooperated as far as possible with this expedition.

Balloon pyrheliometry.—At the same time a cooperating expedition from the United States Weather Bureau made ascents of captive and free balloons in order to determine the temperature, pressure, and humidity at great elevations, for use in reducing Mr. Ångström's observations. Advantage was taken of the opportunity to send up special pyrheliometers for measuring solar radiation at great altitudes. These experiments, which were made jointly by Mr. Aldrich and Mr. Sherry of the Weather Bureau, were referred to by anticipation in last year's report. Five balloon pyrheliometers were sent up from Santa Catalina Island. All were recovered, with readable records. One instrument unfortunately lay in a field about six weeks before recovery, and parts of its record referring to the higher elevations were obliterated, but it yielded the best results of any up to about 8,000 meters. Two of the instruments unfortunately were

PLATE 5.



BALLOON PYRHELIOMETER.

shaded by cirrus clouds until after the mercury froze in their thermometers. The highest elevation at which a radiation record was obtained was about 14,000 meters, or nearly 45,000 feet. As stated in last year's report no results indicating that values of solar radiation exceeding our solar constant value (1.93 calories) are obtainable by pyrheliometric measurements at any elevation, however high, appear from these balloon pyrheliometer experiments. In view of the proposed repetition of the experiments with improved apparatus no further statement of these preliminary results is necessary here.

The tower-telescope work.—As stated in former reports, investigations were carried on at Washington during the years 1904 to 1907 to determine the distribution of the sun's radiation along the diameter of the solar disk. It was shown by this work, in accord with results of earlier observers, that the edge of the solar disk is much less bright than the center, and that this contrast of brightness is very great for violet and ultra-violet rays, but diminishes steadily with increasing wave lengths, and becomes very slight for red and especially for infra-red rays. These phenomena are well shown in the accompanying illustration, from observations of 1913. The measurements were continued at Washington on all suitable days in the hope that some fluctuation of this contrast of brightness between the edge and center of the solar disk would be disclosed. It seemed probable that there might be such fluctuations associated with the irregular variability of the total solar radiation. It proved, however, that such fluctuations, if existing, were of so small an order of magnitude that it was not certain whether they were really shown by the observations at Washington, hampered as these were by variable transparency of the air.

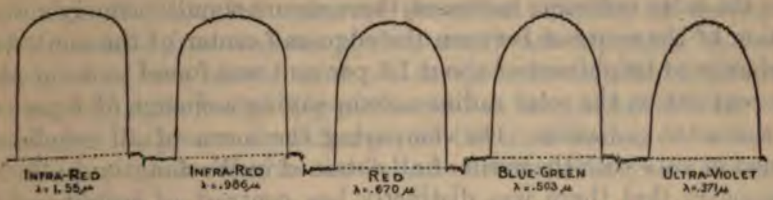


FIG. 1.—Brightness distribution along sun's diameter for different colors.

When the observing station was erected on Mount Wilson in 1908 provision was made for a tower telescope designed to continue this research. When in 1911 and 1912 the Algerian expeditions confirmed the sun's variability, added interest was felt in the proposed experiments. Accordingly, the tower, 50 feet in height, was completed in 1912. Not sufficient funds were available to equip the tower telescope, but Director Hale, of the Mount Wilson Solar Observatory, kindly loaned considerable apparatus, and with this and some apparatus which remained from eclipse expeditions, and by using anything available, as, for instance, a trunk of a tree for a mirror support at the top of the tower, Messrs. Abbot and Aldrich succeeded in getting arranged on the tower a reflecting telescope of 12 inches aperture and 75 feet focus, all ready for observations by September 9, 1913. Then and thereafter solar constant measurements were supplemented by determinations of the distribution of radiation along the sun's diameter on each day of observation. These determinations are made in seven different wave lengths on each day, ranging from 0.38μ in the ultra violet to 1.1μ in the infra-red. Fortunately, the definition of the tower telescope proves to be very good. There is slight change of focus during the several hours of observing, and the "seeing" seems not to deteriorate much up to 10 o'clock a. m., at which time the observations are generally concluded.

About 45 days of simultaneous observations of the "solar constant" and of the distribution of radiation over the sun's disk were secured in 1913. The results appear to indicate a variability in both phenomena and a distinct correlation of the two in point of time. It is indicated that when in course of its short-period irregular variation the solar radiation increases, there occurs simultaneously a diminution of the contrast between the edge and center of the sun's disk. A change of brightness of about 1.5 per cent was found to occur at 95 per cent out on the solar radius accompanying a change of 6 per cent in the solar radiation. On comparing the mean of all results obtained in 1913 with the mean of all obtained in Washington in 1906–7, it appears that there was distinctly less contrast of brightness between the edge and center of the sun's disk in 1913 than in 1907. We have reason, however, to believe that there was distinctly a greater total solar radiation in 1907 than in 1913. This result, compared with the result stated above, indicates a difference of character between the long-period fluctuations of the sun and its short-period irregular fluctuations. The changes of contrast found, however, agree in this, that whether from day to day in 1913, or as between 1913 and 1907, the violet or shorter wave lengths change in contrast more than the red or longer wave lengths.

MOUNT WILSON EXPEDITION OF 1914.

Mr. Abbot continued the Mount Wilson work, beginning in May, 1914. Many improvements were made in the tower telescope, leading to improved definition and stability of the image of the sun. Improved methods of observing were introduced also.

BALLOON PYRHELIOMETRY.

Mr. Aldrich, in cooperation with the United States Weather Bureau observers, under personal direction of Dr. Blair, arranged to repeat the balloon pyrheliometer observations, and this time at

Omaha. Ascensions were not made until after July 1, 1914, but it may be said in anticipation that two ascensions by day and one by night were made. All three instruments were recovered. No unexpected phenomena were disclosed by the night record. One day record appears to be excellent. Fortunately the instrument which recorded it came back uninjured, and further tests and calibrations with it are intended. The instrument reached a very great height, and recorded radiation successfully until after it began to descend. Preliminary reductions show that the values recorded fall below our adopted value of the solar constant of radiation.

SUMMARY.

Progress has been made in the measurement of the effects produced by atmospheric water vapor on solar and terrestrial radiation. New apparatus for measuring sky radiation has been devised and perfected. Special pyrheliometers have been constructed and caused to record solar radiation with considerable success at great altitudes when attached to free balloons. The results obtained tend to confirm the adopted value of the solar constant of radiation. Further results from balloon pyrheliometry are expected. A tower telescope has been erected and put in operation on Mount Wilson. By means of it the variability of the sun has been independently confirmed, for it appears that changes of the distribution of radiation over the sun's disk occur in correlation with the changes of the sun's total radiation.

Respectfully submitted.

C. G. Abbot,
Director Astrophysical Observatory.

Dr. Charles D. Walcott,
Secretary of the Smithsonian Institution.

APPENDIX 6.

REPORT ON THE LIBRARY.

SIR: I have the honor to present the following report upon the work of the Library of the Smithsonian Institution and its branches during the fiscal year ending June 30, 1914:

It is with deep regret that the library records the death, on June 25, 1914, of Dr. Frederick William True, assistant secretary of the Smithsonian Institution in charge of library and exchanges.

ACCESSIONS.

The additions to the library are received, with few exceptions, in exchange for the publications of the Institution or by gift. There were received during the year a total of 32,964 packages of publications, about 90 per cent of which came by mail and the balance through the International Exchange Service. The correspondence incident thereto aggregated about 2,000 written letters and 5,883 printed forms of acknowledgment.

There was catalogued, accessioned, and forwarded to the Smithsonian Deposit in the Library of Congress a total of 32,195 pieces, as follows: 3,765 volumes and 1,729 parts of volumes, 5,755 pamphlets, 20,603 periodicals, and 343 charts. In addition 1,062 parts of serials were received to complete imperfect sets. The accession entries were from 513,027 to 517,776.

There was also transferred to the Library of Congress without being stamped and recorded a total of 7,464 public documents presented to the Institution.

The accessions to the office library, the Astrophysical Observatory, and the National Zoological Park amounted to 1,165 publications, which were distributed as follows: 631 volumes, 93 parts of volumes, 46 pamphlets, and 1 chart were recorded for the office library; 106 volumes, 33 parts of volumes, and 212 pamphlets for that of the Astrophysical Observatory; and 39 volumes and 4 pamphlets for the National Zoological Park. This large increase over the previous year was due in part to the addition of nearly 100 books for the employees' library from the estate of Miss Lucy Hunter Baird and also to books acquired for the use of the Langley Aerodynamical Laboratory.

Complete sets of inaugural dissertations and technological publications from 35 universities and technical high schools were received from the following places: Baltimore, Basel, Berlin, Bern, Bonn, Braunschweig, Breslau, Dresden, Erlangen, Freiburg, Giessen, Greifswald, Halle-Wittenberg, Hamburg, Heidelberg, Helsingfors, Ithaca, Jena, Karlsruhe, Kiel, Konigsberg, Leipzig, Louvain, Lund, Marburg, New Haven, Paris, Rostock, St. Petersburg, Strassburg, Toulouse, Tubingen, Upsala, Wurzburg, and Zurich.

EXCHANGES.

A considerable portion of the periodicals in the Smithsonian Library are obtained in exchange for publications of the Institution. During the year 138 new titles of periodicals were thus added to the large series of scientific journals already contained in the Smithsonian deposit. There were also secured 1,062 parts to complete imperfect sets of publications already in the library.

This work of completing the sets and series in the Smithsonian deposit is of great importance and has been carried forward with definite results.

In response to requests sent to various institutions, 832 missing parts have been supplied to complete 124 sets of publications of scientific institutions and learned societies, 151 parts of 62 periodicals and 78 parts of 30 sets and 1 map for the series in the general classification. Among the more important publications received and sent to the deposit to complete the sets may be mentioned 73 parts of the "Chetniia," of the University of Moscow, Russia, making the set complete from 1869 to date; also 60 parts of the Boletín de la Sociedad Mexicana de Geografía y Estadística, of Mexico City, Mexico, completing the set to date; and 4 sets of publications, comprising 78 volumes, from Het Islenska Bokmentafelag, of Reykjavik, Iceland, completing the sets from 1869 to date.

The securing of publications of historical societies in the United States and abroad has been continued, and many additional publications have been obtained and transmitted to the Library of Congress.

READING ROOM.

The reading room has been in constant use during the year. There are now on file about 270 foreign and domestic scientific periodicals which are required by the staff of the institution and its branches for consultation. In view of the fact that this collection contains representative scientific periodicals from all parts of the world, officers of the scientific bureaus of the various governmental establishments in Washington and students generally continue to take advantage of the opportunity to consult them.

THE AERONAUTICAL LIBRARY.

With the inauguration of the Langley Aerodynamical Laboratory many important works on aeronautics published in the last few years were needed in connection with the work. A specially prepared list made by Dr. A. F. Zahm and Naval Constructor Jerome C. Hunsaker, United States Navy, was considered, and 120 publications not already on the shelves were secured.

ART ROOM.

The collections of works on art have remained practically unchanged during the year. The administration of the National Gallery of Art being now under the National Museum, all books relating to the fine arts formerly assigned to the art room are now placed in the museum library as received.

EMPLOYEES' LIBRARY.

The employees' library has been very fortunate in receiving, through the estate of Miss Lucy Hunter Baird, volumes in addition to those presented by her some years ago, which add interest to the collection of general literature for the use of the employees.

NEW STEEL BOOK STACKS.

In the report on the library for last year the preliminary plans for the new steel book stacks for the main hall of the Smithsonian building were discussed. On March 14, 1914, a contract was entered into for the erection of the stacks in the east end and the completion of the work within 120 days from that date. On February 26, 1914, the wrecking of the galleries had begun with the moving of the books of the Bureau of American Ethnology library, and within 10 days the old galleries had been razed and the old exhibition cases removed, leaving the east end of the hall entirely free. At the end of the year the floor and walls at the east end of the hall had been repaired, the heating plant reinstalled, and the steel framework of the stacks put in place.

These stacks are of steel construction, in three tiers, one on the main floor and two above, the two above having floors of glass. On the east wall is a single-faced stack covering the entire wall area from the floor of the hall to the ceiling. At the two columns second from the east end is erected a double-faced stack, partitioning the stacks from the main hall, and on the west face of this stack are two galleries which are an extension of the floors of the stacks. The stacks between this partition and the east wall have open shelving throughout. A passageway on the lower floor leading to the offices of the Institution in the east end of the building has been provided for, and the openings between the stacks on the sides provided with grill doors in order that the books on these shelves may be protected. The cases on the north and south walls of what is left of the main hall, as well as those under the first gallery, are provided with glass-panel doors in order to protect the contents, as it is the intention to use this hall for museum exhibition purposes.

CATALOGUE OF SMITHSONIAN PUBLICATIONS.

The manuscript of the dictionary catalogue of the publications of the Institution and its branches mentioned in last year's report is still in preparation, but it is expected that it will be ready for publication during the coming year.

UNITED STATES NATIONAL MUSEUM.

The library of the National Museum consists of the main library in the natural history building, to which have been transferred all the publications relating to biology and anthropology as well as those of a general character; the technological series, in the older, or arts and industries building, which at present includes publications relating to technology, and for convenience those on history and botany. These two libraries do not include, however, some 30 sectional libraries in the scientific departments and divisions of the Museum. In making this arrangement the convenience and interests of the scientific staff have been the only consideration. The entire library of the Museum now contains 43,609 volumes, 73,765 pamphlets and unbound papers, and 124 manuscripts. The accessions during the past year were 1,917 volumes, 1,723 pamphlets, and 132 parts of volumes.

In the library of the Museum 755 books were catalogued; 2,001 pamphlets; total number of cards made, 3,520; completed volumes of periodicals catalogued, 1,162; parts of publications, 12,833; parts of periodicals entered, 397; 397 new periodical cards were made, and 8 books and 362 pamphlets were recatalogued.

The number of books, periodicals, and pamphlets borrowed from the general library was 20,884, which includes 9,718 obtained from the Library of Congress, 376 from the Department of Agriculture, 105 from the United States Geological Survey, 90 from the Army Medical Museum and Library, 2 from the United States Bureau of Education, 4 from the United States Patent Office, 4 from the Bureau of Fisheries, 1 from the United States Weather Bureau, 3 from the United States Naval Observatory, and 2 from Harvard University, Cambridge, Mass.

The securing of new exchanges for the Museum has been continued, with the result that many new publications have been added to the catalogue, and much has been done toward securing, in connection with this work, parts of publications.

The moving of the biological, anthropological, and general reference series of the library to the new building having been completed in the previous year and the rearrangement of the publications on the shelves taken up, attention was given to the finishing of this latter task.

DUPLICATE MATERIAL.

For many years the Museum library was overcrowded to such an extent that the shelves had overflowed and it was impossible to have a proper arrangement of the books. With these publications were many duplicates which had been received by gift and otherwise from the very beginning.

Among the duplicate material were many volumes of United States Government documents duplicating publications already on the shelves, and these, being of no further use to the Institution, were transferred to the superintendent of documents, in accordance with law.

BINDING.

The lack of sufficient funds for the binding of publications is a serious question. This will obstruct the work in the future more than in the past, unless an adequate sum can be set aside, so that all the volumes may be bound and made ready for reference. To prepare a volume for binding and then to be obliged to take out parts of it urgently needed by the staff makes it incomplete, and should that part be lost the volume may remain incomplete, inasmuch as the publications which the Museum needs for its work are published in limited editions and it is often impossible again to secure them for binding when there is money available for the purpose.

During the year 690 volumes were prepared for binding and sent to the Government bindery for that purpose.

GIFTS.

Many important gifts were received by the library during the year, the estate of Miss Lucy Hunter Baird being one of the donors. The following members of the staff presented publications: Dr. William Healey Dall, Dr. O. P. Hay, Dr. C. W. Richmond, Dr. Edgar A. Mearns, Mr. Alfred Klakring, and Dr. Harriet Richardson Searle.

BAIRD LIBRARY.

Spencer Fullerton Baird, second secretary of the Smithsonian Institution, gave his valuable scientific library to the United States National Museum when the Museum library was founded. He retained during his lifetime a number of volumes, and after his death his daughter, Miss Lucy Hunter Baird, continued to add to these books. In her will, which was probated after her death last year, she left to the Museum this collection, which numbered 750 volumes.

DALL LIBRARY.

A number of books relating to mollusks was presented to the Museum in 1892 by Dr. William Healey Dall, and he has added to this gift from year to year. The number of titles is now about 7,500, and these, with a comparatively small number of books from other sources, make up the sectional library of the division of mollusks. During the past year Dr. Dall has added about 50 titles. The cataloguing of these books was completed during the past year under Dr. Dall's personal direction.

TECHNOLOGICAL SERIES.

Periodicals entered on the records of the technology library have numbered 476 complete volumes, 6,096 parts of volumes, and the new periodical cards made for these have been 331. The cataloguing for the year numbered 256 volumes and 747 pamphlets, requiring 1,187 separate cards. The total number of cards typewritten, periodical and catalogue, is 1,518. In addition, about 500 volumes and 8,000 pamphlets have been placed on the shelves under their respective class numbers and will be incorporated later in the records which are now in preparation.

Books and pamphlets loaned during the year in addition to those from the general library numbered 188 volumes and 290 single pamphlets and parts of periodicals, making a total number of 478 publications. About 360 books have been consulted in the reading room, and about 3,000 books and periodicals have been transferred to the various sections of mineral technology, textiles, and graphic arts, and section cards made for these.

The science depository set of cards from the Library of Congress was received last year, and about 28,000 have been filed alphabetically. About the same number remain to be filed before the set is in alphabetical order. When completed it will be a useful index to the scientific resources of Washington. The catalogue has been completed for all the books in the reading room and about two-thirds of the east gallery, leaving the north gallery and the remainder of the east gallery still to be done.

SECTIONAL LIBRARIES.

The sectional libraries of the Museum have been receiving reference publications for which receipts have been given and filed in the library, but since the moving to the new building no systematic checking has been done of what is now on the shelves in the libraries placed in the departments and divisions. It seems desirable and important that this matter should receive consideration, and it is recommended that a competent cataloguer be employed to do this special work. It is estimated that it would require a year's time to complete the work.

The sectional libraries now existing are as follows:

Administration.
Administrative assistant's office.
Anthropology.
Biology.
Birds.
Botany.
Comparative anatomy.
Editor's office.
Ethnology.
Fishes.
Geology.
Graphic arts.
History.
Insects.
Invertebrate paleontology.
Mammals.
Marine invertebrates.
Materia medica.
Mechanical technology.
Mollusks.
Oriental archeology.
Paleobotany.
Parasites.
Photography.
Physical anthropology.
Prehistoric archeology.
Reptiles and batrachians.
Superintendent's office.
Taxidermy.
Textiles.
Vertebrate paleontology.

BUREAU OF AMERICAN ETHNOLOGY.

This library is administered under the direct care of the ethnologist in charge, and a report on its operations will be found in the general report of the bureau.

ASTROPHYSICAL OBSERVATORY.

Books relating directly to astrophysics have been brought together for the use of the Observatory. It is a valuable series of technical works and all the publications are in constant use. During the year 351 publications have been added, consisting of 106 volumes, 33 parts of volumes, and 212 pamphlets. There were 64 volumes bound at the Government Printing Office.

NATIONAL ZOOLOGICAL PARK.

The collection of works on zoological subjects, which are kept in the office of the superintendent of the park, is not very large, but they all relate to the work which is being carried on. During the year 39 volumes and 4 pamphlets have been added.

SUMMARY OF ACCESSIONS.

The following statement summarizes the accessions during the year, with the exception of the library of the Bureau of American Ethnology:

To the Smithsonian deposit in the Library of Congress, including parts to complete sets	12,654
To the Smithsonian office, Astrophysical Observatory, and Zoological Park	1,165
To the United States National Museum	3,772
Total	17,591

Respectfully submitted.

Paul Brockett,
Assistant Librarian.

Dr. Charles D. Walcott,
Secretary of the Smithsonian Institution.

APPENDIX 7.

REPORT ON THE INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE.

SIR: I have the honor to submit the following report on the operations of the United States Bureau of the International Catalogue of Scientific Literature for the year ending June 30, 1914:

This enterprise was organized in 1901 and has for its object the preparation and publication of an annual classified index to the current literature of science. The catalogue is published in the form of a classified book index, each paper referred to being first listed under the author's name and again under the subject or subjects of the contents. Seventeen main volumes are issued each year, one for each of the following-named branches of science: Mathematics, mechanics, physics, chemistry, astronomy, meteorology, mineralogy, geology, geography, paleontology, general biology, botany, zoology, anatomy, anthropology, physiology, and bacteriology.

All of the first 9 annual issues have been published, together with 16 volumes of the tenth issue, 8 volumes of the eleventh issue, and 1 volume of the twelfth, a total of 178 regular volumes, in addition to several special volumes of schedules, lists of journals, etc. The number of pages in each annual issue is shown in the following table:

	Pages.
First annual issue	7,763
Second annual issue	8,826
Third annual issue	8,493
Fourth annual issue	8,681
Fifth annual issue	10,785
Sixth annual issue	10,049
Seventh annual issue	9,219
Eighth annual issue	8,699
Ninth annual issue	7,933
Tenth annual issue	8,447

The large increase in size of the fifth and sixth annual issues necessitated a change in the plan of publication, the object in view being to reduce the bulk and consequent cost of the work while not reducing its usefulness. This has been accomplished by printing the full titles and references only once—that is, in the author catalogue—the subject catalogue containing only the author's name and a number referring to a like number in the author's catalogue where the full reference may be found. Following this plan has resulted in a marked reduction in the size of the eighth, ninth, and tenth issues.

The central bureau of the organization is maintained in London and has charge of receiving, editing, and publishing the classified references furnished by the 33 regional bureaus cooperating in the production of the catalogue. These regional bureaus are maintained for the most part by direct governmental grants made by the countries in which they are situated. The annual subscription price for a complete set of 17 volumes is $85. The proceeds derived from subscriptions are used entirely to support the central bureau.

During the year 28,606 cards were sent from this bureau to the London central bureau, as follows:

Literature of—	
1905	169
1906	64
1907	133
1908	621
1909	223
1910	852
1911	2,988
1912	8,010
1913	15,546
Total	28,606

The following table shows the number of cards sent each year as well as the number of cards representing the literature of each year from 1901 to 1913, inclusive:

Literature of—	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	Total for year.
Year ending June 30—														
1902	6,990	......	......	......	......	......	......	......	......	......	......	......	......	6,990
1903	6,150	8,330	......	......	......	......	......	......	......	......	......	......	......	14,480
1904	3,044	9,424	8,745	......	......	......	......	......	......	......	......	......	......	21,213
1905	1,619	2,780	11,143	8,640	......	......	......	......	......	......	......	......	......	24,182
1906	301	622	3,538	12,139	9,001	......	......	......	......	......	......	......	......	25,601
1907	384	511	862	5,272	9,022	12,578	......	......	......	......	......	......	......	28,629
1908	408	523	366	956	5,629	7,217	13,429	......	......	......	......	......	......	28,528
1909	133	235	373	309	1,656	4,410	8,509	18,784	......	......	......	......	......	34,409
1910	72	173	248	465	1,163	1,502	3,160	6,305	11,994	......	......	......	......	25,082
1911	3	26	28	218	129	374	423	1,301	8,836	14,682	......	......	......	26,020
1912	......	......	4	243	386	562	1,480	1,949	3,372	5,231	13,974	......	......	27,201
1913	......	9	5	12	14	131	226	324	685	3,214	6,950	16,425	......	27,995
1914	......	......	......	......	169	64	133	621	223	852	2,988	8,010	15,546	28,606
Total	19,104	22,633	25,312	28,254	27,169	26,838	27,360	29,284	25,110	23,979	23,912	24,435	15,546	318,936

As has been pointed out in several previous annual reports, this enterprise is in no sense commercial, and should be freed from the necessity of depending entirely on subscription for its maintenance. A comparatively small endowment would materially aid in improving the form and expanding the scope of the index to include some of the applied sciences. Could this be done, it is more than probable that increased demands would more than make up for increased expense, for when the catalogue meets the demands of the applied sciences, as it now does those of pure science, it will become a general work of reference for all branches of arts and industries. The organization is complete and satisfactory, and its usefulness could be greatly increased by the expenditure of a comparatively small sum annually.

No advance or improvement can, however, be undertaken until an assured additional income becomes available.

The International Catalogue was originally organized by a number of international conferences, the third of which met in London in July, 1900. The delegates there assembled provided that an international convention should meet in London in 1905, in 1910, and every tenth year thereafter to reconsider and revise, if necessary, the regulations governing the enterprise.

It was provided also that an international council should meet in London at least once every three years to regulate the affairs of the catalogue between two successive meetings of the convention. A meeting of this international council was held June 11 and 12, 1914, and after authorizing the necessary contracts for the continuation of the enterprise and disposing of a number of other routine matters, discussed the very vital question of altering and revising the classification schedules. It was provided that further alteration would best be made by the introduction of subdivisions to the now existing schedules, such subdivisions to be suggested by the regional bureaus as the need for them should appear.

Very respectfully, yours,

LEONARD C. GUNNELL,
Assistant in Charge.

DR. CHARLES D. WALCOTT,
Secretary of the Smithsonian Institution.

APPENDIX 8.

REPORT ON THE PUBLICATIONS.

SIR: I have the honor to submit the following report on the publications of the Smithsonian Institution and its branches during the year ending June 30, 1914:

The Institution proper published during the year 36 papers in the series of "Smithsonian Miscellaneous Collections," an annual report, and pamphlet copies of 38 papers from the general appendix of the report. The Bureau of American Ethnology published 2 bulletins and a separate paper, and the United States National Museum issued 2 annual reports, 49 miscellaneous papers from the proceedings, 9 new bulletins and parts, and 9 parts of volumes pertaining to the National Herbarium.

The total number of copies of publications distributed by the Institution proper during the year was 107,471. The aggregate includes 1,229 volumes of Smithsonian Contributions to Knowledge; 59,777 volumes and separates of Smithsonian Miscellaneous Collections; 23,279 volumes and separates of the Smithsonian annual reports; 6,483 special publications; 1,477 copies of volume 3, Annals of the Astrophysical Observatory; 775 reports of the Harriman Alaska Expedition; 12,819 volumes and separates of the Bureau of American Ethnology publications; 1,412 annual reports of the American Historical Association; 26 publications of the United States National Museum; and 194 publications not of the Smithsonian Institution or its branches. Additional copies of the third edition of the Smithsonian Geographical Tables were printed just before the close of the year. There were also distributed by the National Museum 93,200 copies of its several publications, making a total of 202,671 publications distributed by the Institution and its branches during the year.

SMITHSONIAN CONTRIBUTIONS TO KNOWLEDGE.

QUARTO.

No publications of this series were issued during the year.

SMITHSONIAN MISCELLANEOUS COLLECTIONS.

OCTAVO.

Of the Miscellaneous Collections, volume 57, 3 papers were published; of volume 59, 1 paper, and title-page and table of contents; of volume 60, 2 papers, and title-page and table of contents; of volume 61, 21 papers, and title-page and table of contents; of volume 62, 2 papers; of volume 63, 6 papers; and of volume 64, 1 paper; in all, 36 papers, as follows:

Volume 57.

No. 11. Cambrian geology and paleontology. II. New Lower Cambrian subfauna. By Charles D. Walcott. Published July 21, 1913. Pp. 309–326, pls. 50–54. (Publ. 2185.)

No. 12. Cambrian geology and paleontology. II. Cambrian formations of the Robson Peak district, British Columbia and Alberta, Canada. By Charles D. Walcott. July 24, 1913. Pp. 327–343, pls. 55–59. (Publ. 2186.)

No. 13. Cambrian geology and paleontology. II. Dikelocephalus and other genera of the Dikelocephalinæ. By Charles D. Walcott. April 4, 1914. Pp. 345–412 and index, pls. 60–70. (Publ. 2187.)

[Title-page and table of contents.] (Publ. 2270.) In press.

Volume 59.

No. 19. Early Norse Visits to North America. By William H. Babcock. July 9, 1913. iii+213 pp., 10 pls.

Title-page and table of contents. vi pp. August 7, 1913. (Publ. 2234.)

Volume 60.

No. 23. The influence of the atmosphere on our health and comfort in confined and crowded places. By Leonard Hill, Martin Flack, James McIntosh, R. A. Rowlands, and H. B. Walker. Hodgkins Fund. July 15, 1913. 96 pp. (Publ. 2170.)

No. 30. Explorations and field work of the Smithsonian Institution in 1912. March 28, 1913. 76 pp., 82 figs. (End of volume.) (Publ. 2178.)

Title-page and table of contents. August 7, 1913. vi pp. (Publ. 2235.)

Volume 61.

No. 1. The White Rhinoceros. By Edmund Heller. October 11, 1913. 77 pp., 31 pls. (Publ. 2180.) [Nos. 2 to 5 of this volume were published during previous year.]

No. 6. Great stone monuments in history and geography. By J. Walter Fewkes. September 15, 1913. 50 pp. (Publ. 2229.)

No. 7. New races of antelopes from British East Africa. By Edmund Heller. July 31, 1913. 13 pp. (Publ. 2231.)

No. 8. The comparative histology of the femur. By Dr. J. S. Foote. August 22, 1913. 9 pp., 3 pls. (Publ. 2232.)

No. 9. Descriptions of three new African weaver birds of the genera Estrilda and Granatina. By Edgar A. Mearns. July 31, 1913. 4 pp. (Publ. 2236.)

No. 10. Descriptions of four new African thrushes of the genera Planesticus and Geocichla. By Edgar A. Mearns. August 11, 1913. 5 pp. (Publ. 2237.)

No. 11. Descriptions of six new African birds. By Edgar A. Mearns. August 30, 1913. 5 pp. (Publ. 2238.)

No. 12. Populus Macdougalii. A new tree from the Southwest. By J. N. Rose. September 3, 1913. 2 pp., 1 pl. (Publ. 2239.)

No. 13. New antelopes and carnivores from British East Africa. By Edmund Heller. September 16, 1913. 15 pp. (Publ. 2240.)

No. 14. Descriptions of five new African weaver birds of the genera Othyphantes, Hypargos, Aidemosyne, and Lagonostica. By Edgar A. Mearns. September 20, 1913. 5 pp. (Publ. 2241.)

No. 15. Notes on the recent crinoids in the British Museum. By Austin Hobart Clark. December 31, 1913. 89 pp. (Publ. 2242.)

No. 16. A new shrub of the genus Esenbeckia from Colombia. By Dr. K. Krause. September 29, 1913. 1 p. (Publ. 2243.)

No. 17. New races of ungulates and primates from Equatorial Africa. By Edmund Heller. October 21, 1913. 12 pp. (Publ. 2245.)

No. 18. Anthropological work in Peru in 1913, with notes on the pathology of the ancient Peruvians. By Dr. Aleš Hrdlička. February 12, 1914. 69 pp., 26 pls. (Publ. 2246.)

No. 19. New races of carnivora and baboons from Equatorial Africa and Abyssinia. By Edmund Heller. November 8, 1913. 12 pp. (Publ. 2248.)

No. 20. Descriptions of 10 new African birds of the genera Pogonocichla, Cossypha, Bradypterus, Sylvietta, Melaniparus, and Zosterops. By Edgar A. Mearns. November 29, 1913. 8 pp. (Publ. 2251.)

No. 21. Fifty-one new Malayan mammals. By Gerrit S. Miller, jr. December 29, 1913. 30 pp. (Publ. 2252.)

No. 22. Four new subspecies of large mammals from Equatorial Africa. By Edmund Heller. January 26, 1914. 7 pp. (Publ. 2255.)

No. 23. A new genus of Mallophaga from African guinea fowl in the United States National Museum. By John Howard Paine. January 31, 1914. 4 pp. (Publ. 2258.)

No. 24. New Sapindaceæ from Panama and Costa Rica. By Prof. Dr. L. Radlkofer. February 9, 1914. 8 pp. (Publ. 2259.)

No. 25. Descriptions of eight new African Bulbuls. By Edgar A. Mearns. February 16, 1914. 6 pp. (Publ. 2260.)

Title-page and table of contents. March 13, 1914. vi pp. (Publ. 2265.)

Volume 62.

No. 1. Advisory Committee on the Langley Aerodynamical Laboratory. Hodgkins Fund. July 17, 1913. 5 pp. (Publ. 2227.)

No. 2. Hydromechanic experiments with flying-boat hulls. By H. C. Richardson. Hodgkins Fund. April 20, 1914. 9 pp., 6 pls. (Publ. 2253.)

No. 3. Report on European aeronautical laboratories. By A. F. Zahm. 23 pp., 11 pls. (Publ. 2273.) In press.

Volume 63.

No. 1. Atmospheric air in relation to tuberculosis. By Guy Hinsdale. Hodgkins Fund. June 22, 1914. 136 pp., 93 pls. (Publ. 2254.)

No. 2. Notes on some specimens of a species of Onychophore (Oroperipatus corradoi) new to the fauna of Panama. By Austin Hobart Clark. February 21, 1914. 2 pp. (Publ. 2261.)

No. 3. A new Ceratopsian dinosaur from the Upper Cretaceous of Montana, with note on Hypacrosaurus. By Charles W. Gilmore. March 21, 1914. 10 pp., 2 pls. (Publ. 2262.)

No. 4. On the relationship of the genus Aulacocarpus, with description of a new Panamanian species. By H. Pittier. March 18, 1914. 4 pp. (Publ. 2264.)

No. 5. Descriptions of five new mammals from Panama. By E. A. Goldman. March 14, 1914. 7 pp. (Publ. 2266.)

No. 6. Physical Tables. Sixth edition. F. E. Fowle. (Publ. 2269.) In press.

No. 7. New subspecies of mammals from Equatorial Africa. By Edmund Heller. June 24, 1914. 12 pp. (Publ. 2272.)

Volume 64.

No. 1. Cambrian geology and paleontology. III. The Cambrian Faunas of Eastern Asia. By Charles D. Walcott. April 22, 1914. Pp. 1–76, pls. 1–3. (Publ. 2263.)

No. 2. Cambrian geology and paleontology. III. Pre-Cambrian Algonkian Algal Flora. By Charles D. Walcott. Pp. 77–156, pls. 4–23. (Publ. 2271.) In press.

SMITHSONIAN ANNUAL REPORTS.

Report for 1912.

The Annual Report of the Board of Regents for 1912 was received from the Public Printer in completed form in October, 1913.

Annual Report of the Board of Regents of the Smithsonian Institution, showing operations, expenditures, and condition of the Institution for the year ending June 30, 1912. xii, 780 pp., 72 pls. (Publ. 2188.)

Small editions of the following papers, forming the general appendix of the annual report for 1912, were issued in pamphlet form:

The year's progress in astronomy. By P. Puiseux. 8 pp. (Publ. 2189.)

The spiral nebulæ. By P. Puiseux. 10 pp. (Publ. 2190.)

The radiation of the sun. By C. G. Abbot. 13 pp., 4 pls. (Publ. 2191.)

Molecular theories and mathematics. By Émile Borel. 20 pp. (Publ. 2192.)

Modern mathematical research. By G. A. Miller. 12 pp. (Publ. 2193.)

The connection between the ether and matter. By Henri Poincaré. 12 pp. (Publ. 2194.)

Experiments with soap bubbles. By C. V. Boys. 8 pp., 1 pl. (Publ. 2195.)

Measurements of infinitesimal quantities of substances. By William Ramsay. 11 pp. (Publ. 2196.)

The latest achievements and problems of the chemical industry. By Carl Duisberg. 26 pp. (Publ. 2197.)

Holes in the air. By W. J. Humphreys. 12 pp., 2 pls. (Publ. 2198.)

Review of applied mechanics. By L. Lecornu. 16 pp. (Publ. 2199.)

Report on the recent great eruption of the volcano "Stromboli." By Frank A. Perret. 5 pp., 9 pls. (Publ. 2200.)

The glacial and postglacial lakes of the Great Lakes region. By Frank B. Taylor. 37 pp. (Publ. 2201.)

Applied geology. By Alfred H. Brooks. 24 pp. (Publ. 2202.)

The relations of paleobotany to geology. By F. H. Knowlton. 6 pp. (Publ. 2203.)

Geophysical research. By Arthur L. Day. 11 pp. (Publ. 2204.)

A trip to Madagascar, the country of beryls. By A. Lacroix. 12 pp. (Publ. 2205.)

The fluctuating climate of North America. By Ellsworth Huntington. 30 pp., 10 pls. (Publ. 2206.)

The survival of organs and the "culture" of living tissues. By R. Legendre. 8 pp., 4 pls. (Publ. 2207.)

Adaptation and inheritance in the light of modern experimental investigation. By Paul Kammerer. 21 pp., 8 pls. (Publ. 2208.)

The paleogeographical relations of antarctica. By Charles Hedley. 11 pp. (Publ. 2209.)

The ants and their guests. By P. E. Wasmann. 20 pp., 10 pls. (Publ. 2210.)

The penguins of the antarctic regions. By L. Gain. 8 pp., 9 pls. (Publ. 2211.)

The derivation of the European domestic animals. By C. Keller. 9 pp. (Publ. 2212.)

Life: its nature, origin, and maintenance. By E. A. Schäfer. 33 pp. (Publ. 2213.)

The origin of life: a chemist's fantasy. By H. E. Armstrong. 15 pp. (Publ. 2214.)

The appearance of life on worlds and the hypothesis of Arrhénius. By Alphonse Berget. 9 pp. (Publ. 2215.)

The evolution of man. By G. Elliot Smith. 20 pp. (Publ. 2216.)

The history and varieties of human speech. By Edward Sapir. 23 pp. (Publ. 2217.)

Ancient Greece and its slave population. By S. Zaborowski. 12 pp. (Publ. 2218.)

Origin and evolution of the blond Europeans. By Adolphe Bloch. 22 pp. (Publ. 2219.)

History of the finger-print system. By Berthold Laufer. 22 pp., 7 pls. (Publ. 2220.)

Urbanism: A historic, geographic, and economic study. By Pierre Clerget. 15 pp. (Publ. 2221.)

The Sinai problem. By E. Oberhummer. 9 pp., 3 pls. (Publ. 2222.)

The music of primitive peoples and the beginnings of European music. By Willy Pastor. 22 pp. (Publ. 2223.)

Expedition to the South Pole. By Roald Amundsen. 16 pp. (Publ. 2224.)

Icebergs and their location in navigation. By Howard T. Barnes. 24 pp., 3 pls. (Publ. 2225.)

Henri Poincaré, his scientific work, his philosophy. By Charles Nordmann. 23 pp. (Publ. 2226.)

Report for 1913.

The report of the executive committee and proceedings of the Board of Regents of the Institution, as well as the report of the Secretary for the fiscal year ending June 30, 1913, both forming part of the annual report of the Board of Regents to Congress, were published in pamphlet form in November and December, respectively, 1913, as follows:

Report of the executive committee and proceedings of the Board of Regents for the year ending June 30, 1913. 21 pp. (Publ. 2250.)

Report of the Secretary of the Smithsonian Institution for the year ending June 30, 1913. iii, 119 pp., 1 pl. (Publ. 2249.)

The general appendix to the Smithsonian Report for 1913 was in type, but actual presswork was not completed at the close of the fiscal year. In the general appendix are the following papers:

The earth and sun as magnets, by George E. Hale.

The reaction of the planets upon the sun, by P. Puiseux.

Recent progress in astrophysics, by C. G. Abbot.

The earth's magnetism, by L. A. Bauer.

Modern ideas on the end of the world, by Gustav Jaumann.

Recent developments in electromagnetism, by Eugene Bloch.

Wireless transmission of energy, by Elihu Thomson.

Oil films on water and on mercury, by Henri Devaux.

Water and volcanic activity, by Arthur L. Day and E. S. Shepherd.

Ripple marks, by Ch. Epry.

Notes on the geological history of the walnuts and hickories, by Edward W. Berry.

The formation of leafmold, by Frederick V. Coville.

The development of orchid cultivation and its bearing upon evolutionary theories, by J. Costantin.

The manufacture of nitrates from the atmosphere, by Ernest Kilburn Scott.

The geologic history of China and its influence upon the Chinese people, by Eliot Blackwelder.

The problems of heredity, by E. Apert.

Habits of fiddler-crabs, by A. S. Pearse.

The abalones of California, by Charles L. Edwards.

The value of birds to man, by James Buckland.

Experiments in feeding hummingbirds during seven summers, by Althea R. Sherman.

What the American Bird Banding Association has accomplished during 1912, by Howard H. Cleaves.

The whale fisheries of the world, by Charles Rabot.

The most ancient skeletal remains of man, by Aleš Hrdlička.

The redistribution of mankind, by H. N. Dickson.

The earliest forms of human habitation, and their relation to the general development of civilization, by M. Hoernes.

Feudalism in Persia; its origin, development, and present condition, by Jacques de Morgan.

Shintoism and its significance, by K. Kanokogi.

The Minoan and Mycenaean element in Hellenic life, by A. J. Evans.

Flameless combustion, by Carleton Ellis.

Problems in smoke, fume, and dust abatement, by F. G. Cottrell.

Twenty years' progress in marine construction, by Alexander Gracie.

Creating a subterranean river and supplying a metropolis with mountain water, by J. Bernard Walker and A. Russell Bond.

The application of the physiology of color vision in modern art, by Henry G. Keller and J. J. R. Macleod.

Fundamentals of housing reform, by James Ford.

The economic and social rôle of fashion, by Pierre Clerget.

The work of J. van't Hoff, by G. Bruni.

SPECIAL PUBLICATIONS.

The following publications were issued in octavo form:

Classified list of Smithsonian publications available for distribution April 25, 1914. Published April 25, 1914. vi+32 pp. (Publ. 2268.)

Publications of the Smithsonian Institution issued between January 1 and June 30, 1913. July 15, 1913. 2 pp. (Publ. 2228.)

Publications of the Smithsonian Institution issued between January 1 and September 30, 1913. October 14, 1913. 4 pp. (Publ. 2244.)

Publications of the Smithsonian Institution issued between January 1 and December 31, 1913. January 22, 1914. 4 pp. (Publ. 2257.)

Publications issued by the Smithsonian Institution between January 1 and March 31, 1914. April 10, 1914. 1 p. (Publ. 2267.)

Opinions rendered by the International Commission on Zoological Nomenclature, Opinions 57–65. March 26, 1914. Pp. 131–169. (Publ. 2256.)

An account of the exercises on the occasion of the presentation of the Langley Medal and the unveiling of the Langley Memorial Tablet, May 6, 1913, including the addresses. October 13, 1913. 26 pp., 4 pls. (Publ. 2233.)

Harriman Alaska series.

Vol. 14. Monograph of shallow-water starfishes of the north Pacific coast from the Arctic Ocean to California. Part I, text; part II, plates. By Addison Emery Verrill. April 30, 1914. xii+408 pp., 110 pls. (Publ. 2140.)

PUBLICATIONS OF THE UNITED STATES NATIONAL MUSEUM.

The publications of the National Museum are: (*a*) The annual report to Congress; (*b*) the proceedings of the United States National Museum; and (*c*) the bulletin of the United States National Museum, which includes the contributions from the United States National Herbarium. The editorship of these publications is vested in Dr. Marcus Benjamin.

The publications issued by the National Museum during the year comprised 49 papers of the proceedings, 2 annual reports, 9 bulletins and parts, and 9 parts of Contributions from the National Herbarium.

The issues of the proceedings were as follows: Vol. 45, papers 1976, 1985, 2005, 2006, and 2007; vol. 46, papers 2008 to 2042, inclusive; vol. 47, papers 2043 to 2051, inclusive; Annual Report of the United States National Museum for 1912; and Annual Report of the United States National Museum for 1913.

The bulletins were as follows:

Bulletin 50, part 6, Birds of North and Middle America. By Robert Ridgway.

Bulletin 71, part 3, A monograph of the Foraminifera of the North Pacific Ocean, Part III, Lagenidæ. By Joseph Augustine Cushman.

Bulletin 71, part 4, A monograph of the Foraminifera of the North Pacific Ocean, Part IV, Chilostomellidæ, Globigerinidæ, Nummulitidæ. By Joseph Augustine Cushman.

Bulletin 80. A descriptive account of the building recently erected for the departments of natural history of the United States National Museum. By Richard Rathbun.

Bulletin 83. Type species of the genera of Ichneumon flies. By Henry L. Viereck.

Bulletin 84. A contribution to the study of Ophiurans of the United States National Museum. By Rene Koehler.

Bulletin 85. A monograph of the jumping plant lice or Psyllidæ of the New World. By David L. Crawford.

Bulletin 86. A monograph of the genus Chordeiles Swainson, type of a new family of goatsuckers. By Harry C. Oberholser.

Bulletin 87. Culture of the ancient pueblos of the upper Gila River region, New Mexico and Arizona. By Walter Hough.

In the series of Contributions from the National Herbarium there appeared:

Volume 16.

Part 10. Annona sericea and its allies. By William E. Safford.

Part 11. Nomenclature of the Sapote and the Sapodilla. By O. F. Cook.

Part 12. A monograph of the Hauyeæ and Gongylocarpeæ, tribes of the Onagraceæ. By J. Donald Smith and J. N. Rose.

Part 13. Botrychium virginianum and its forms Sphenoclea zeylanica and Caperonia palustris in the southern United States. By Ivar Tidestrom.

Volume 17.

Part 3. Mexican grasses in the United States National Herbarium. By A. S. Hitchcock.

Part 4. Studies of tropical American ferns. By William R. Maxon.

Part 5. Studies of tropical American Phanerogams—No. 1. By Paul C. Standley.

Volume 18.

Part 1. Classification of the genus Annona with descriptions of new and imperfectly known species. By W. E. Safford.

Part 2. New or noteworthy plants from Colombia and Central America—4. By Henry Pittier.

There was also reprinted an edition of 200 copies each of parts A, K, and P of Bulletin 39, United States National Museum, directions for collecting birds, by Robert Ridgway, directions for collecting and preparing fossils, by Charles Schuchert, directions for collectors of American basketry, by Otis T. Mason; an edition of 500 copies of Bulletin 67, directions for collecting and preserving insects, by Nathan Banks; an edition of 2,000 copies of list of publications issued by the United States National Museum from 1906 to 1912, reprinted from annual reports with altered pagination; and an edition of 1,300 copies of a list of publications of the United States National Museum issued during the fiscal year 1912–13, reprinted from the annual report with altered pagination.

PUBLICATIONS OF THE BUREAU OF AMERICAN ETHNOLOGY.

The publications of the bureau are discussed in Appendix 2 of the Secretary's report. The editorial work is in the charge of Mr. J. G. Gurley, who has been assisted from time to time by Mrs. Frances S. Nichols.

Two bulletins and a "separate" from another bulletin were issued during the year, as follows:

Bulletin 53. Chippewa music—II. By Frances Densmore.

Bulletin 56. Ethnozoology of the Tewa Indians. By Junius Henderson and John P. Harrington.

Coos: An illustrative sketch. By Leo J. Frachtenberg. Extract from Handbook of American Indian Languages (Bulletin 40), part 2.

At the close of the year two annual reports and several bulletins were in press.

PUBLICATIONS OF THE SMITHSONIAN ASTROPHYSICAL OBSERVATORY.

Volume III, Annals of the Smithsonian Astrophysical Observatory, by C. G. Abbot, F. E. Fowle, and L. B. Aldrich. July 16, 1913, xi+241 pp., 7 pls. (Publ. 2230.)

PUBLICATIONS OF THE AMERICAN HISTORICAL ASSOCIATION.

The annual reports of the American Historical Association are transmitted by the association to the Secretary of the Smithsonian Institution, and are communicated to Congress under the provisions of the act of incorporation of the association.

Volumes 1 and 2 of the annual report for 1911 were published November 10, 1913, and January 14, 1914, respectively, with contents as follows:

Volume I.

Report of the proceedings of the twenty-seventh annual meeting of the American Historical Association. By Waldo G. Leland, secretary.
Report of the proceedings of the eighth annual meeting of the Pacific coast branch. By H. W. Edwards, secretary of the branch.
The archives of the Venetian Republic. By Theodore F. Jones.
Materials for the history of Germany in the sixteenth and seventeenth centuries. By Sidney B. Fay.
The materials for the study of the English cabinet in the eighteenth century. By Edward Raymond Turner.
François de Guise and the taking of Calais. By Paul van Dyke.
Factions in the English privy council under Elizabeth. By Conyers Read.
Anglo-Dutch relations, 1671–72. By Edwin W. Pahlow.
American-Japanese intercourse prior to the advent of Perry. By Inazo Nitobe.
Colonial society in America. By Bernard Moses.
French diplomacy and American politics, 1794–95. By James Alton James.
The insurgents of 1811. By D. R. Anderson.
The tariff and the public lands from 1828 to 1833. By Raynor G. Wellington.
The "Bargain of 1844" as the origin of the Wilmot proviso. By Clark E. Persinger.
Monroe and the early Mexican revolutionary agents. By Isaac Joslin Cox.
Public opinion in Texas preceding the Revolution. By Eugene C. Barker.
Relations of America with Spanish America, 1720–1744. By H. W. V. Temperley.
The genesis of the Confederation of Canada. By Cephas D. Allin.
Proceedings of the eighth annual conference of historical societies.
List of European historical societies.
Twelfth report of the public archives commission. By Herman V. Ames, chairman.
  Appendix A. Proceedings of the third annual conference of archivists.
  Appendix B. Report on the archives of the State of Colorado. By James F. Willard.
  Appendix C. List of commissions and instructions to governors and lieutenant governors of American and West Indian Colonies, 1609–1784.
Writings on American history, 1911. By Grace G. Griffin.

Volume II.

Ninth report of the historical manuscripts commission: Correspondence of Alexander Stephens, Howell Cobb, and Robert Toombs.

The report for 1912 was sent to the printer on January 31, 1914, and at the close of the year was nearly ready for distribution. The contents are as follows:

Report of the proceedings of the twenty-eighth annual meeting of the American Historical Association.
Report of the proceedings of the ninth annual meeting of the Pacific coast branch. By H. W. Edwards, secretary of the branch.
Royal finances of the reign of Henry III. By Henry L. Cannon.
Antecedents of the Quattrocento. By Henry O. Taylor.
The new Columbus. By Henry P. Biggar.
The charter of Connecticut. By Clarence W. Bowen.
The enforcement of the alien and sedition acts. By Frank M. Anderson.
The reviewing of historical books. By Carl Becker.
Briefer papers read in conferences:
  A. Libya as a field of research. By Oric Bates.
  B. The international character of commercial history. By Abbott P. Usher.
  C. Some new manuscript sources for the history of modern commerce. By N. S. B. Gras.
  D. The study of South American commercial history. By Charles L. Chandler.
  E. On the economics of slavery, 1815–1860. By Ulrich B. Phillips.
  F. On the history of Pennsylvania, 1815–1860. By P. Orman Ray.
  G. Historical research in the far west. By Katherine Coman.
Proceedings of the conference on military history.
Proceedings of the ninth annual conference of historical societies:
  Genealogy and history. By Charles K. Bolton.
The Massachusetts Historical Society.. By Worthington C. Ford.
Appendix: Reports of historical societies, 1912.
Thirteenth report of the Public Archives Commission:
  Appendix A. Proceedings of the fourth annual conference of archivists.
    Plan and scope of a "Manual of Archival Economy for the use of American Archivists." By Victor H. Paltsits.
    Some fundamental principles in relation to archives. By Waldo G. Leland.
    The adaptation of archives to public use. By Dunbar Rowland.
  Appendix B. Report on the archives of the State of Louisiana. By Prof. William O. Scroggs.
  Appendix C. Report on the archives of the State of Montana. By Paul C. Phillips.
Classified list of publications of the American Historical Association, 1885–1912.
Tenth report of the historical manuscripts commission:
  Letters of William Vans Murray to John Quincy Adams, 1797–1803. Edited by Worthington C. Ford.

PUBLICATIONS OF THE SOCIETY OF THE DAUGHTERS OF THE AMERICAN REVOLUTION.

The manuscript of the Sixteenth Annual Report of the National Society of the Daughters of the American Revolution for the year ending October 11, 1913, was communicated to Congress June 16, 1914.

THE SMITHSONIAN ADVISORY COMMITTEE ON PRINTING AND PUBLICATION.

The editor has continued to serve as secretary of the Smithsonian advisory committee on printing and publication. To this committee have been referred the manuscripts proposed for publication by the various branches of the Institution, as well as those offered for printing in the Smithsonian publications. The committee also considered forms of routine, blanks, and various matters pertaining to printing and publication, including the qualities of paper suitable for text and plates. Twenty meetings were held and 121 manuscripts were acted upon.

Respectfully submitted.

A. Howard Clark, *Editor.*

Dr. Charles D. Walcott,
Secretary of the Smithsonian Institution.

REPORT OF THE EXECUTIVE COMMITTEE OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION FOR THE YEAR ENDING JUNE 30, 1914.

To the Board of Regents of the Smithsonian Institution:

Your executive committee respectfully submits the following report in relation to the funds, receipts, and disbursements of the Institution, and a statement of the appropriations by Congress for the National Museum, the International Exchanges, the Bureau of American Ethnology, the National Zoological Park, the Astrophysical Observatory, and the International Catalogue of Scientific Literature for the year ending June 30, 1914, together with balances of previous appropriations:

SMITHSONIAN INSTITUTION.

Condition of the fund July 1, 1914.

The permanent fund of the Institution and the sources from which it has been derived are as follows:

DEPOSITED IN THE TREASURY OF THE UNITED STATES.

Bequest of Smithson, 1846		$515, 169.00
Residuary legacy of Smithson, 1867		26, 210.63
Deposit from savings of income, 1867		108, 620.37
Bequest of James Hamilton, 1875	$1, 000.00	
Accumulated interest on Hamilton fund, 1895	1, 000.00	
		2, 000.00
Bequest of Simeon Habel, 1880		500.00
Deposits from proceeds of sale of bonds, 1881		51, 500.00
Gift of Thomas G. Hodgkins, 1891		200, 000.00
Part of residuary legacy of Thomas G. Hodgkins, 1894		8, 000.00
Deposit from savings of income, 1903		25, 000.00
Residuary legacy of Thomas G. Hodgins, 1907		7, 918.69
Deposit from savings of income, 1913		636.94
Bequest of William Jones Rhees, 1913		251.95
Deposit of proceeds from sale of real estate (gift of Robert Stanton Avery), 1913		9, 692.42
Bequest of Addison T. Reid, 1914		4, 795.91
Deposit of savings from income of Avery bequest, 1914		204.09
Total amount of fund in the United States Treasury		960, 500.00

OTHER RESOURCES.

Registered and guaranteed bonds of the West Shore Railroad Co., part of legacy of Thomas G. Hodgkins (par value)	42, 000.00
Total permanent fund	1, 002, 500.00

Also three small pieces of real estate located in the District of Columbia and bequeathed by Robert Stanton Avery, of Washington, D. C.

That part of the fund deposited in the Treasury of the United States bears interest at 6 per cent per annum, under the provisions of the act of Congress of August 10, 1846, organizing the Institution, and the act approved March 12, 1894. The rate of interest on the West Shore Railroad bonds is 4 per cent per annum. The real estate received from Robert Stanton Avery is exempt from taxation and yields only a nominal revenue from rentals.

Statement of receipts and disbursements from July 1, 1913, to June 30, 1914.

RECEIPTS.

Cash on deposit July 1, 1913		$33,641.40
Interest on fund deposited in United States Treasury, due July 1, 1913, and Jan. 1, 1914	$57,314.29	
Interest on West Shore Railroad bonds, due July 1, 1913, and Jan. 1, 1914	1,680.00	
Repayments, rentals, publications, etc	9,638.14	
Contributions from various sources for specific purposes	17,554.20	
Bequest of Addison T. Reid	4,795.91	
		90,982.54
		124,623.94

DISBURSEMENTS.

Buildings, care and repairs		$5,578.43
Furniture and fixtures		1,755.91
General expenses:		
Salaries	$18,969.72	
Meetings	102.00	
Stationery	743.25	
Postage, telegraph, and telephone	594.87	
Freight	100.31	
Incidentals, fuel, and lights	1,052.23	
Garage	2,973.29	
		24,535.67
Library		2,390.50
Publications and their distribution:		
Contributions to Knowledge	$25.00	
Miscellaneous collections	5,864.28	
Reports	617.43	
Special publications	454.88	
Publication supplies	776.92	
Salaries	6,971.48	
		14,709.99
Explorations, researches, and collections		16,142.88
Hodgkins specific fund, researches, and publications		6,601.85
International Exchanges		4,752.70
Gallery of Art		431.80
Advances for field expenses, etc		11,431.40

Deposited to credit of permanent fund		$5,000.00
Langley Aerodynamical Laboratory		723.73
		94,063.81
Balance, June 30, 1914, deposited with the Treasurer of the United States	$30,360.13	
Cash on hand	200.00	
		124,623.94

By authority your executive committee again employed Mr. William L. Yaeger, a public accountant of this city, to audit the receipts and disbursements of the Smithsonian Institution during the period covered by this report. The following certificate of examination supports the foregoing statement and is hereby approved:

EXECUTIVE COMMITTEE, BOARD OF REGENTS,
Smithsonian Institution.

SIRS: I have examined the accounts and vouchers of the Smithsonian Institution for the fiscal year ending June 30, 1914, and certify the following to be a correct statement:

Total disbursements	$94,063.81
Total receipts	90,982.54
Excess of disbursements over receipts	3,081.27
Amount from July 1, 1913	33,641.40
Balance on hand June 30, 1914	30,560.13
Balance shown by Treasury statement June 30, 1914	34,779.94
Less outstanding checks	4,419.81
	30,360.13
Cash on hand	200.00
True balance June 30, 1914	30,560.13

The vouchers representing payments from the Smithsonian income during the year, each of which bears the approval of the secretary, or, in his absence, of the acting secretary, and a certificate that the materials and services charged were applied to the purposes of the Institution, have been examined in connection with the books of the Institution and agree with them.

(Signed) WILLIAM L. YAEGER,
Public Accountant and Auditor.

AUGUST 10, 1914.
Certified a true copy.

W. I. ADAMS,
Accountant, Smithsonian Institution.

All moneys received by the Smithsonian Institution from interest, sales, refunding of moneys temporarily advanced, or otherwise, are deposited with the Treasurer of the United States to the credit of the Institution, and all payments are made by checks signed by the secretary.

The expenditures made by the disbursing agent of the Institution and audited by the Auditor for the State and other Departments are reported in detail to Congress and will be found in the printed document.

Your committee also presents the following summary of appropriations for the fiscal year 1914 intrusted by Congress to the care of the Smithsonian Institution, balances of previous appropriations at the beginning of the fiscal year, and amounts unexpended on June 30, 1914:

	Available after July 1, 1913.	Balance June 30, 1914.
Appropriations committed by Congress to the care of the institution:		
International Exchanges, 1912	$0.31	[1] $0.31
International Exchanges, 1913	4,065.41	.02
International Exchanges, 1914	32,000.00	1,622.22
American Ethnology, 1912	50.56	[1] 45.31
American Ethnology, 1913	4,288.61	1,250.74
American Ethnology, 1914	42,000.00	2,676.68
Astrophysical Observatory, 1912	612.59	[1] 225.59
Astrophysical Observatory, 1913	516.38	142.42
Astrophysical Observatory, 1914	13,000.00	779.87
Bookstacks, Government bureau libraries, 1914	15,000.00	13,559.77
International Catalogue, 1912	25.95	[1] 25.95
International Catalogue, 1913	681.58	291.73
International Catalogue, 1914	7,500.00	720.09
National Museum—		
Furniture and fixtures, 1912	1.54	[1] 1.54
Furniture and fixtures, 1913	11,617.95	42.58
Furniture and fixtures, 1914	50,000.00	10,369.30
Heating and lighting, 1912	124.68	[1] 124.68
Heating and lighting, 1913	12,689.65	151.81
Heating and lighting, 1914	50,000.00	5,902.35
Preservation of collections, 1912	1,355.75	[1] 440.85
Preservation of collections, 1913	17,393.57	3,659.15
Preservation of collections, 1914	300,000.00	7,652.72
Books, 1912	26.54	[1] 24.70
Books, 1913	845.21	10.67
Books, 1914	2,000.00	1,091.35
Postage, 1914	500.00	
Building repairs, 1912	18.44	[1] 18.44
Building repairs, 1913	576.05	1.14
Building repairs, 1914	10,000.00	1,298.78
Building, National Museum	1,613.25	[1] 1,613.25
National Zoological Park, 1912	186.83	[1] 1.83
National Zoological Park, 1913	9,459.75	9.18
National Zoological Park, 1914	100,000.00	6,210.30
Bridge over Rock Creek, National Zoological Park	18,224.02	3,018.67

[1] Carried to credit of surplus fund.

Statement of estimated income from the Smithsonian fund and from other sources, accrued and prospective, available during the fiscal year ending June 30, 1915.

Balance June 30, 1914		$30,560.13
Interest on fund deposited in United States Treasury, due July 1, 1914, and Jan. 1, 1915	$57,630.00	
Interest on West Shore Railroad bonds, due July 1, 1914, and Jan. 1, 1915	1,680.00	
Exchange repayments, sale of publications, refund of advances, etc	13,882.85	
Deposits for specific purposes	12,405.00	
		85,597.85
Total available for year ending June 30, 1915		116,157.98

Respectfully submitted.

ALEXANDER GRAHAM BELL,
MAURICE CONNOLLY,
Executive Committee.

WASHINGTON, D. C.,

PROCEEDINGS OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION FOR THE FISCAL YEAR ENDING JUNE 30, 1914.

ANNUAL MEETING, JANUARY 15, 1914.

Present: The Hon. Edward D. White, Chief Justice of the United States, chancellor, in the chair; the Hon. Thomas R. Marshall, Vice President of the United States; Senator A. O. Bacon; Senator Henry Cabot Lodge; Senator William J. Stone; Representative Scott Ferris; Representative Maurice Connolly; Representative Ernest W. Roberts; Dr. Andrew D. White; Dr. A. Graham Bell; Judge George Gray; Mr. John B. Henderson, jr.; and the secretary, Mr. Charles D. Walcott.

The chancellor explained that this was the annual meeting adjourned from December 11, 1913.

DEATH OF REGENT.

The secretary announced the death, on December 22, 1913, of the Hon. Irvin S. Pepper, Member of the House of Representatives, who was originally appointed Regent in December, 1911, and reappointed December 10, 1913, for the ensuing two years.

Mr. Ferris submitted the following resolution, which was adopted:

> Whereas the Board of Regents of the Smithsonian Institution having learned of the death, on December 22, 1913, of the Hon. Irvin S. Pepper, Member of the House of Representatives and a Regent of the Institution since December, 1911: Therefore be it
>
> *Resolved*, That the board desire here to record their sorrow at the loss of a colleague whose untimely death terminates a career filled with promise and whose interest in the affairs of the Institution made him a most valuable member of the board.

APPOINTMENT OF REGENTS.

The secretary announced the appointment by the Speaker of the following Members of the House of Representatives:

The Hon. Scott Ferris, reappointed.

The Hon. Maurice Connolly, to succeed Mr. Pepper, deceased.

The Hon. Ernest W. Roberts, to succeed Mr. John Dalzell, whose term of office had expired.

EXECUTIVE COMMITTEE VACANCY.

On motion, the following resolution was adopted:

Resolved, That the vacancy in the membership of the executive committee be filled by the election of the Hon. Maurice Connolly.

RESOLUTION RELATIVE TO INCOME AND EXPENDITURE.

Senator Bacon, chairman of the executive committee, offered the following resolution, which was adopted:

Resolved, That the income of the Institution for the fiscal year ending June 30, 1915, be appropriated for the service of the Institution, to be expended by the secretary with the advice of the executive committee, with full discretion on the part of the secretary as to items.

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE.

Senator Bacon, chairman, submitted the report of the executive committee for the fiscal year ending June 30, 1913.

On motion, the report was adopted.

ANNUAL REPORT OF THE PERMANENT COMMITTEE.

Hodgkins fund.—This fund has undergone no changes since the last report. The following allotments have been made from its revenues during the year:

To Mr. C. G. Abbot and Dr. Ångström for conducting experiments in nocturnal radiation.

By formal action of the board, certain allotments were authorized for immediate use in inaugurating the work of the proposed Langley Aerodynamical Laboratory.

The board will recall that in connection with the International Congress on Tuberculosis, held in the National Museum in 1908, the Institution offered a Hodgkins prize of $1,500 for the best treatise on "The Relation of Atmospheric Air to Tuberculosis." Nearly a hundred papers were submitted, and after a most exhaustive examination of the essays by all the members of the advisory committee, which for various reasons encountered many delays, the award has been made, and the prize divided equally between Dr. Guy Hinsdale, of Hot Springs, Va., for his paper on "Tuberculosis in Relation to Atmospheric Air," and Dr. S. Adolphus Knopf, of New York City, whose essay is entitled "On the Relation of Atmospheric Air to Tuberculosis."

Avery bequest.—Two of the parcels of land included in this bequest have been sold for a total of $9,692.42, which sum has been deposited to the credit of the permanent fund of the Institution in the United States Treasury.

Poore bequest.—The matters in relation to the settlement of the Poore estate, which have had the supervision of Mr. Choate, have progressed satisfactorily.

A report on the financial condition of the estate to November 15, 1913, has been submitted by the executor, Mr. John J. Pickman, who says that claims against the estate are being adjusted as rapidly as circumstances will permit. Your committee asks that the board refer the matter of final settlement to it with power to act. Mr. Pickman reports that the whole estate may ultimately amount to from $35,000 to $40,000.

Under the terms of the bequest, this is to be allowed to increase to $250,000, the income of which will then become available for the purposes of the Institution.

Research Corporation.—During the past year the corporation has established the Cottrell process in a number of plants in order to demonstrate its commercial practicability, and new plants are being installed as rapidly as the engineering force can do the work.

Other patents have been offered to the corporation and are under consideration. One of these is for a concrete tie, which is now being thoroughly tested on one of the railways in southwestern California.

Addison T. Reid bequest.—In 1903 the board was informed of a proposed bequest to the Institution from Mr. Addison T. Reid, of Brooklyn, N. Y., to found a chair of biology in memory of the testator's grandfather, Asher Tunis. The bequest was subject to the condition that the income was to be paid in three equal shares to certain enumerated legatees until their death, when the principal of the estate, with accumulations, was to come to the Institution. At that time the estate was estimated to be worth $10,000.

Recently the Institution has been informed of the death of one of the beneficiaries, and the trust created for her benefit, amounting to $4,795.91, has been paid to the Institution and deposited to the credit of the permanent fund in the United States Treasury.

Will of Morris Loeb.—At the meeting of February 13, 1913, the board's attention was called to an item in the will of Morris Loeb, of New York City, in which the Institution is made a residual legatee and is to receive a one-tenth share of the estate remaining upon the death of the testator's wife. This legacy is to be used for the furtherance of knowledge in the exact sciences.

The Lucy Hunter Baird bequest.—Miss Baird, daughter of Spencer Fullerton Baird, late secretary of the Institution, died June 19, 1913, making provision for the Institution and National Museum in the following items of her will:

> Fourth. * * * To the National Museum in the City of Washington, D. C., all articles deposited by my father, Spencer F. Baird, my mother, Mary H. C. Baird, or myself, in its keeping or that of the Smithsonian Institution with the exception of the specific bequests to the Smithsonian Institu-

tion contained in this will. If there be any china of which I have made no other disposition, of any value to the Museum, I desire that it shall be placed therein.

To the Smithsonian Institution the copies of my father's own books containing his notes in his own handwriting, also the books by Audubon or any other works on natural history, annotated in my father's writing, to be kept forever in a case together.

To the National Museum or to the Smithsonian Institution as my executor shall deem best any pictures or books not otherwise disposed of, which they may desire.

* * * * * * *

Sixth. Upon the release of any portion of the said trust estate by the death of the person entitled to the income therefrom, unless otherwise provided in paragraph fifth, I give, devise, and bequeath the same to the Smithsonian Institution in trust as a fund to be known as "The Spencer Fullerton Baird fund," the interest from which shall be devoted under the direction of the Smithsonian Institution to the expenses in whole or in part of a scientific exploration and biological research or for the purchase of specimens of natural objects or archaeological specimens.

The Chamberlain bequest.—The late Rev. Dr. Leander T. Chamberlain, of New York City, married in 1890 Frances Lea, the daughter of Dr. Isaac Lea, of Philadelphia, publisher and eminent naturalist, who had made an extensive collection of fresh-water mussels and exhaustive researches into their life history. Dr. Lea died in 1886, bequeathing this collection to the National Museum. To his daughter he left a large collection of gems and precious stones. She died in 1894, bequeathing this collection to the National Museum. Mrs. Chamberlain took a deep interest in "the Isaac Lea collections" in the Museum, adding to them by direct gifts of specimens and by money for their purchase. Upon her death Dr. Chamberlain assumed her trust in the Lea collections, and in consequence of his gifts and collaboration he was appointed "associate in mineralogy" in the Museum. Upon his death (May 9, 1913) it was learned that his will contained the following provisions in regard to the Isaac Lea collections:

Seventh. I give and bequeath to the Smithsonian Institution, in the city of Washington and District of Columbia, the sum of twenty-five thousand dollars ($25,000), in trust, the same to constitute a permanent fund, which shall be known as the "Frances Lea Chamberlain fund," the income of said fund to be used, under the direction of the secretary of the Board of Regents of said Institution, for promoting the increase, and the scientific value and usefulness, of the collection of gems and gem material known as the "Isaac Lea collection" in the department of minerals in the United States National Museum, the said collection having been chiefly collected and given by me in honor of Dr. Isaac Lea and his only daughter, Frances Lea Chamberlain.

Eighth. I give and bequeath to the Smithsonian Institution, in the city of Washington and District of Columbia, the further sum of ten thousand dollars ($10,000), the same to constitute a permanent fund, which shall be known as the "Frances Lea Chamberlain fund," the income of said fund to be used, under the direction of the secretary of the Board of Regents of said Institution, for promoting the scientific value and usefulness of the collection of mollusks known as the "Isaac Lea collection," in the department of mollusks in said Smithsonian Institution.

The Riter Fitzgerald bequest.—The will of Mr. Fitzgerald, of Philadelphia, who died in 1911, dated May 19, 1910, and first brought to the attention of the Institution in March, 1913, contains an item in which the National Museum is concerned, as follows:

> I give, devise, and bequeath to my executors, hereinafter named, and the survivor of them, or their successors in the trust, all the rest, residue, and remainder of my estate, real, personal, and mixed, and wheresoever situate, including all of my portion, share, and interest in the estate of my late father, Thomas Fitzgerald, deceased, both real, personal, and mixed, in trust nevertheless, to invest the same and collect the rents, interest, and income as it accrues, and pay over the net income thereof quarterly to my niece, Geraldine Maud Hubbard, daughter of my sister, Maud Hubbard, for and during the term of her natural life, her receipt alone to be a sufficient release and discharge therefor, and so that the same shall not be liable for the debts or engagements of any husband which my niece may have. And upon the decease of my said niece, the principal and accrued interest is to be equally divided betwen her then surviving child or children in equal shares. In the event of the decease of my said niece without leaving a child or children surviving her, then I direct that the principal of my estate, and the interest accrued thereon, shall be given by my executors and trustees, and the survivor of them, or their successors in trust, to the United States National Museum of the Smithsonian Institution, Washington, D. C.

This part of the estate is appraised at between $12,000 and $13,000.

The Joseph White Sprague bequest.—The committee desires to refresh the memory of the Regents as to the terms of this bequest. It will be recalled that in 1901 the board's attention was drawn to the proposed bequest of Mr. Sprague, whose residence was Louisville, Ky. His will provides that 85 per cent of the total income of the estate is to be distributed among certain devisees until their death and then to several of their relatives for 20 years after the death of the last devisee, when the trust expires by limitation and is to be paid to the Smithsonian Institution and to be known as "the Sprague fund." Its purpose is to best promote the advancement of the physical sciences, and only one-half of each annual income is to be used, the other half to be added to the principal of the estate. In 1901 it was estimated that the estate was worth $200,000. The terms imposed by the will indicate that the acquisition of the fund by the Institution will be at a remote date.

Respectfully submitted.

A. O. BACON.
ALEXANDER GRAHAM BELL.
JOHN DALZELL.
CHARLES D. WALCOTT.

On motion, the report was adopted.

On motion of Senator Bacon, the secretary was requested to publish in his annual report a synopsis of the permanent committee's report.

JOHN B. HENDERSON MEMORIAL.

The committee appointed to prepare for the records of the board a suitable minute relating to the late Regent, John Brooks Henderson, submitted its report as follows:

GENTLEMEN: Your committee appointed at the meeting of May 1, 1913, for the purpose of preparing a suitable minute of the life and work of the late Hon. John B. Henderson, a former Regent of the Institution, begs to submit the following:

John Brooks Henderson, doctor of laws, a member of the Board of Regents of the Smithsonian Institution from January 26, 1892, to March 1, 1911, was born near Danville, Va., on November 16, 1826, and died at Takoma Park, D. C., April 12, 1913.

For 19 years, until failing health compelled him to retire from active duties, he had a deep official and personal interest in the activities of the Institution, serving during that entire period as a member of the executive committee, for 15 years its chairman, and for 17 years as a member of the permanent committee. His sound judgment and wise counsel as a jurist were of great assistance to his associates in their deliberations on important and perplexing problems of policy and administration.

At an early age he moved from Virginia to Missouri, where he received an academic education and supported himself as a teacher while studying law. He was admitted to the bar in 1848 and in 1882 was honored with the degree of LL. D. by the University of Missouri. From 1848 to 1856 he served in the State legislature; was presidential elector in 1856 and 1860; United States Senator from January 29, 1862, to March 3, 1869; commissioner to treat with hostile Indians in 1867; United States district attorney in 1875; and chairman of the Chicago convention in 1884. In 1861 he organized a brigade of Missouri State Militia and was appointed brigadier general.

On January 11, 1864, after conferences with President Lincoln and without the knowledge of any other person, Mr. Henderson presented in the Senate the joint resolution abolishing slavery which afterwards became the thirteenth amendment to the Federal Constitution.

In 1890 he moved from Missouri to Washington City, and resided there until his death, leading a life of retirement, although taking great interest in public matters and philanthropic work and in the affairs of several scientific and patriotic organizations of which he was a member.

Mr. Henderson was a lawyer, a statesman, a soldier, a financier, and in all these callings he was successful. The secret of his success was an alert mind, a natural executive ability, strong will, courage, and an independence that fixed his course though he walked alone.

During his long life Mr. Henderson enjoyed an intimate friendship with many men eminent in the social, political, and business life of the Nation, all of whom held him in the highest esteem.

He was one of the men who make history, and in his death a highly honorable career was brought to a close.

Respectfully,

GEO. GRAY,
H. C. LODGE,
CHARLES D. WALCOTT.

On motion, the report was accepted.

SECRETARY'S ANNUAL REPORT.

The secretary presented his report on the operations of the Institution for the fiscal year ending June 30, 1913.

In regard to publications, he said:

"The publications issued by the Institution and its branches since the last annual meeting of the board aggregate about 6,500 printed pages covering the usual wide range of topics, and there have been distributed about 190,000 copies of pamphlets and bound volumes.

"The Institution proper published 40 papers in the Smithsonian Miscellaneous Collections; the annual report for 1912, and pamphlet copies of 38 papers from the general appendix of that volume. The Bureau of American Ethnology issued an annual report and three bulletins, and the National Museum publications included 96 papers from the Proceedings, an annual report, and a number of articles relating to the National Herbarium. The results of observations and experiments by the Astrophysical Observatory for 1907 to 1913 are recorded in Volume III of its Annals.

"One of the bulletins of the Museum prepared by Assistant Secretary Rathbun gives an interesting descriptive illustrated account of the new building erected more especially for the natural history departments. A paper in the Miscellaneous Collections gives the results of experiments to determine the influence of the atmosphere on our health and comfort in confined and crowded places, from which it appears that the essentials for good ventilation are mainly to keep the air in motion, comfortably cooled, and containing the proper degree of moisture, its actual chemical purity being of minor importance.

"Among important works in preparation I may mention a complete list of publications of the Institution and its branches since its establishment, the list including about 12,000 titles of articles and volumes."

On motion, the report was accepted.

THE SECRETARY'S STATEMENT.

The secretary made personal statements as follows:

Langley Day exercises.—The exercises arranged for Langley Day, May 6, 1913, were conducted as outlined, and a printed account of the occasion, which included the presentation of two Langley medals and the dedication of the Langley memorial tablet, has been sent to each regent.

Langley Aerodynamical Laboratory.—In accordance with the resolutions adopted at the meeting of the board on May 1, 1913, authorizing the reopening of the Langley Aerodynamical Laboratory and the enlargement of the same, I addressed a letter on May 8, 1913, to President Wilson, asking his approval of the cooperation with this Institution of the Departments of War, Navy, Agriculture, and Commerce, to which the President replied as follows:

THE WHITE HOUSE,
Washington, May 9, 1913.

MY DEAR DR. WALCOTT: Allow me to acknowledge the receipt of your letter of May 8 and to say that I shall take pleasure in sending copies of your letter to the Secretaries of War, Navy, Agriculture, and Commerce, expressing my full approval of the designation of representatives of those departments upon the committee which you are forming for the study of the subject of aeronautics under the authorization of the Board of Regents of the Smithsonian Institution on May 1, 1913.

Cordially and sincerely, yours,

WOODROW WILSON.

Dr. CHARLES WALCOTT,
Smithsonian Institution.

Representatives were thereupon designated by the heads of the four departments mentioned, and on May 23, 1913, the first meeting of the advisory committee of the Langley Aerodynamical Laboratory was held at the Institution. The present membership of the committee is as follows:

Brig. Gen. George P. Scriven and Maj. Edgar Russel, War Department.
Capt. W. I. Chambers and Naval Constructor H. C. Richardson, Navy Department.
Dr. W. J. Humphreys, Department of Agriculture (Weather Bureau).
Dr. S. W. Stratton, Department of Commerce (Bureau of Standards).
Mr. Orville Wright.
Mr. Glenn H. Curtiss.
Mr. John Hays Hammond, jr.
Col. Samuel Reber.
Dr. Albert F. Zahm.
Mr. Charles D. Walcott, secretary of the Smithsonian Institution, chairman.

Included in the organization of the advisory committee was the formation of 16 subcommittees, covering practically every phase of aeronautic work. With their membership recruited from the leading experts all over the country, these subcommittees enable the Langley Laboratory to command the most authoritative advice and assistance obtainable.

As a preliminary step in starting the work of the laboratory, Dr. A. F. Zahm, the recorder of the advisory committee, was sent to visit the principal aerodynamical laboratories near London, Paris, and Gottingen, in company with Assistant Naval Constructor Jerome C. Hunsaker, United States Navy.

Dr. Zahm's trip proved most satisfactory, and his report will contain valuable data for the committee.

Three meetings of the advisory committee have been held, and its work has progressed to such an extent as to render necessary the transmission to Congress of an estimate for an appropriation of $50,000, which received the President's approval. There is also need for a tract of land and water near Washington suitable for tests with experimental air craft, and, as chairman of the advisory committee, I requested the President's approval of the use for this purpose of the portion of Potomac Park east of the railroad embankment, which the committee believes to be the best site for the purpose. It appears, however, that in the opinion of the War Department, authority for such use of the park rests alone with Congress.

Freer gallery of art.—The secretary exhibited elevation and floor plans of a proposed building for the art gallery to be erected by Mr. Charles L. Freer for the collections donated by him to the Institution, stating that a trust fund of $1,000,000 had been set aside by Mr. Freer for its construction.

In answer to inquiries the secretary said that the collections were now thought to represent an expenditure, exclusive of the building, of about $1,750,000.

Building for art objects.—Large numbers of art objects are being received by the Institution almost weekly for the National Gallery of Art. Urgent necessity exists for a proper place for their care and exhibit, as the space now devoted to their use in the new building of the National Museum is more and more needed for the natural history collections. The present art objects represent a value of about $1,000,000, and I wish to urge upon the members of the board the importance of a very early consideration of the question of requesting Congress to provide for the erection of a building adequate for the national art collections.

Expeditions.—The various expeditions under the auspices of the Institution, concerning which reports have been made to the board from time to time have, with few exceptions, been completed.

Borneo expedition.—This expedition is still in the field. Dr. W. L. Abbott, a collaborator of the National Museum, provided $8,000 for its expenses, and under his general direction the collecting is being carried on by Mr. H. C. Raven. Two shipments have been received by the Institution, that include 557 mammals and 560 birds, with skins and skeletons of crocodiles and giant lizards. Mr. Raven expects to remain in Borneo for another year.

British Columbia expedition.—The Secretary briefly reviewed his field work and studies in Cambrian geology during the summer of 1913.

Solar radiation expedition.—Mr. C. G. Abbot, Director of the Astrophysical Observatory of the Institution, spent several months in California during the summer and fall of 1913, in continuation of studies on the variation of the solar constant. The special work of the year was in connection with the variability of the brightness of different parts of the sun. A tower telescope was constructed on Mount Whitney (14,500 feet) and numerous observations made, which it is hoped will furnish an independent check on the variations to which the sun now appears to be subject. As a further test of the results obtained and to overcome any objections that might be made in scientific circles as to their soundness, Mr. Abbot devised a special self-recording pyrheliometer which may be attached to a sounding balloon and sent up entirely free from any connection with the earth to the greatest height to which balloons may penetrate the atmosphere. Five such instruments were constructed at the Astrophysical Observatory in 1913, and, with the cooperation of the United States Weather Bureau, they were sent up by observers of that bureau from Catalina Island, Cal., about the end of July. All were recovered, and although the apparatus had been untried up to that time, three of the instruments gave valuable records, taken at altitudes as great as 50,000 feet. These observations have not yet been definitely reduced, but the preliminary results indicate that just such values were found as will confirm in a very satisfactory manner the conclusions already reached. Some of the balloons ascended over 100,000 feet (19 miles), but owing to the intense cold no records were made, the mercury in the Smithsonian pyrheliometers having frozen. The lowest temperature recorded by the instruments of the Weather Bureau was 76° F. below zero, which is far lower than the freezing point of mercury. It is expected to renew the experiments next spring, when measures will be taken to prevent the freezing of the mercury, and it is hoped then to obtain temperature records at altitudes of 100,000 feet or more.

Biological work in North China.—At the annual meeting on December 12, 1912, the board was informed that Mr. A. de C. Sowerby was making collections in North China for the National Museum, through the liberality of a gentleman who desired that his identity be not disclosed. The same condition prevails now.

Mr. Sowerby has recently notified the Institution of the shipment, principally from Manchuria, of 121 specimens, including squirrels, hog deer, moles, voles (a species of mouse), rats, chipmunks, shrews, hedgehogs, weasels, and badgers, many of which are thought to be new species. He will continue his expedition in North and West Shansi and in the Hei-lung-chang region of Manchuria.

Extension of National Zoological Park.—The sundry civil act for the fiscal year ending June 30, 1914, approved June 23, 1913, contains an item of $107,200 for the purchase of the land lying between the present western boundary of the Zoological Park and Connecticut Avenue, between Cathedral Avenue and Klingle Road. This extension will give the park a frontage of about 1,750 feet on Connecticut Avenue and a considerable area of quite level land much needed for paddocks for bison, deer, and other ruminant animals.

The proposed purchase embraces over 10 acres, and will bring the total area of the park to about 180 acres.

Work under the Harriman trust fund.—Under the special trust fund of $12,000 per annum established by Mrs. E. H. Harriman for his investigations in natural history and ethnology, Dr. C. Hart Merriam is conducting research work in Washington, D. C., and in California. His principal work during the year has been on the Big Bears of America, a group he has been studying for upward of 20 years, and concerning which he now has a monograph nearly ready for publication. In furtherance of this study, specimens have been generously placed at his disposal, not only by numerous sportsmen and hunters but also by all of the larger museums of America, including the Government museums of Canada at Ottawa and Victoria.

Award of Loubat Prize to Dr. John R. Swanton.—In 1893 the Duc de Loubat founded two prizes to be awarded every five years for—

"The best work printed and published in the English language on the history, geography, archæology, ethnology, philology, or numismatics of North America. The competition for such prizes shall be open to all persons."

Dr. John R. Swanton, one of the ethnologists of the Bureau of American Ethnology, has recently been awarded one of these prizes, which carries with it a money consideration of $400, for his two works published by the bureau entitled "Tlingit Myths and Texts" and "Indian Tribes of the Lower Mississippi Valley and Adjacent Coasts of the Gulf of Mexico."

Exhibits.—After informal remarks, in which Vice President Marshall urged an appropriation for preserving the language of the Miami Indians from extinction and Dr. Bell spoke of Mr. Abbot's work in connection with the reduction of the solar constant, the secretary called the board's attention to some special exhibits of anthropological, mineral, and biological material in the adjoining rooms, which also included the pyrheliometer used by Mr. Abbot.

GENERAL APPENDIX

TO THE

SMITHSONIAN REPORT FOR 1914.

ADVERTISEMENT.

The object of the GENERAL APPENDIX to the Annual Report of the Smithsonian Institution is to furnish brief accounts of scientific discovery in particular directions; reports of investigations made by collaborators of the institution; and memoirs of a general character or on special topics that are of interest or value to the numerous correspondents of the institution.

It has been a prominent object of the Board of Regents of the Smithsonian Institution, from a very early date, to enrich the annual report required of them by law with memoirs illustrating the more remarkable and important developments in physical and biological discovery, as well as showing the general character of the operations of the institution; and this purpose has, during the greater part of its history, been carried out largely by the publication of such papers as would possess an interest to all attracted by scientific progress.

In 1880 the secretary, induced in part by the discontinuance of an annual summary of progress which for 30 years previous had been issued by well-known private publishing firms, had prepared by competent collaborators a series of abstracts, showing concisely the prominent features of recent scientific progress in astronomy, geology, meteorology, physics, chemistry, mineralogy, botany, zoology, and anthropology. This latter plan was continued, though not altogether satisfactorily, down to and including the year 1888.

In the report for 1889 a return was made to the earlier method of presenting a miscellaneous selection of papers (some of them original) embracing a considerable range of scientific investigation and discussion. This method has been continued in the present report for 1914.

THE RADIATION OF THE SUN.[1]

By C. G. Abbot, D. Sc.,
Director Astrophysical Observatory, Smithsonian Institution.

[With 4 plates.]

It is really extraordinary how much has been found out about the sun, when it is considered that the sun lies at the immense distance of 93,000,000 miles. There are various methods of ascertaining the distance of the sun, resting upon extremely diverse foundations, so that the close accord of their results to within about one-tenth of 1 per cent gives us great confidence in the accuracy of the mean value. The angular diameter of the sun is also known to a great accuracy, and from this and the distance one determines at once that the diameter of the sun is 865,000 miles. How great this is as compared with the diameter of the earth—7,918 miles! From a consideration of the motions of the earth and the moon it is found that the mass of the sun is 332,800 times the mass of the earth. In accordance with this, the gravitation on the sun is enormous compared with that upon the earth, so that a body which weighs 100 pounds at the earth's surface would be pulled toward the center of the sun from the sun's surface with a force of nearly 1½ tons.

In accordance with the measurements of the diameter and the mass of the sun, it follows that the average density of the material composing the sun is very much less than that composing the earth. In fact, it comes out that the sun's material has only 1.41 times the density of water, whereas the mean density of the material composing the earth is 5.5 times the density of water. Notwithstanding this remarkable fact, it has been shown by spectroscopic work that the heavy metallic elements, such as iron, nickel, zinc, tin, copper, and others, occur in the sun as well as in the earth. The explanation for the discrepancy of density between the two bodies lies probably in the very high temperature of the sun, so that the elements found there are in the form of gases, whereas upon the earth they are in the form of solids. We shall return to this fact later.

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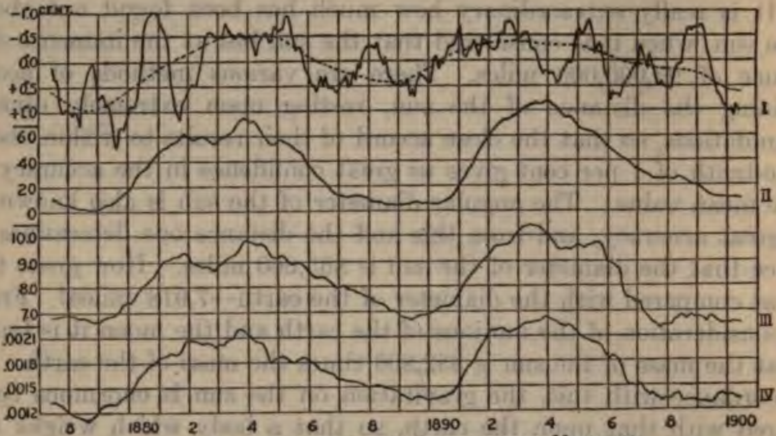
[1] Presented at the meeting of the Section of Physics and Chemistry held Thursday, Jan. 8, 1914. Reprinted by permission from the Journal of The Franklin Institute, June, 1914.

Fig. 1 on pl. 1 is from The Astrophysical Journal, by permission of The University of Chicago Press. Text fig. 1; fig. 2, pl. 1; and pls. 2 and 3 are from Abbot's The Sun, by permission of D. Appleton & Co.

As viewed through the telescope, the sun at first sight is a very disappointing object as compared with the moon. Nevertheless, there is much of interest to be seen there. In the illustration (pl. 1, fig. 1) we see a direct photograph of the sun as obtained by Slocum, of the Yerkes Observatory, on May 18, 1910. Several interesting features may be pointed out. In the first place, note the falling off of the brightness of the disk toward the edges of the sun. In the second place, one sees in the original photograph all over the sun's surface a sort of mottled appearance, not very distinct, but yet interesting. In the third place, in this particular photograph, appear some dark spots, called sun spots. Sun spots were discovered by Galileo in the year 1610, soon after the invention of the telescope.[1] They are distinguished by dark central parts, called the umbra, surrounded by a fringe of less darkness, called the penumbra. The spots shown in the illustration are very large ones, although they seem very small upon the surface of the sun. This is because of the immense diameter of the sun itself. The earth might be dropped into one of these sun spots without much more than filling the umbra, leaving a generous space for the penumbra outside of it.



SUN-SPOTS AND TERRESTRIAL TEMPERATURES AND MAGNETISM.
I. Temperature departures, United States inland stations.
II. Sun-spot relative numbers (Wolf's).
III. Magnetic declination } mean diurnal range
IV. Magnetic horizontal force } Ellis, Chree.

FIG. 1.

It was found by Schwabe, about the middle of the nineteenth century, that sun spots occur most plentifully in periods of about 11 years between maxima. This may be seen by the diagram (fig. 1), in which the second curve represents the prevalence of sun spots according to the so-called sun-spot numbers published by Wolfer. The two lower curves represent, respectively, variations in the earth's

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[1] Sun spots had occasionally been seen with the naked eye earlier, but it was not until 1610 that they were definitely regarded as a solar phenomenon.

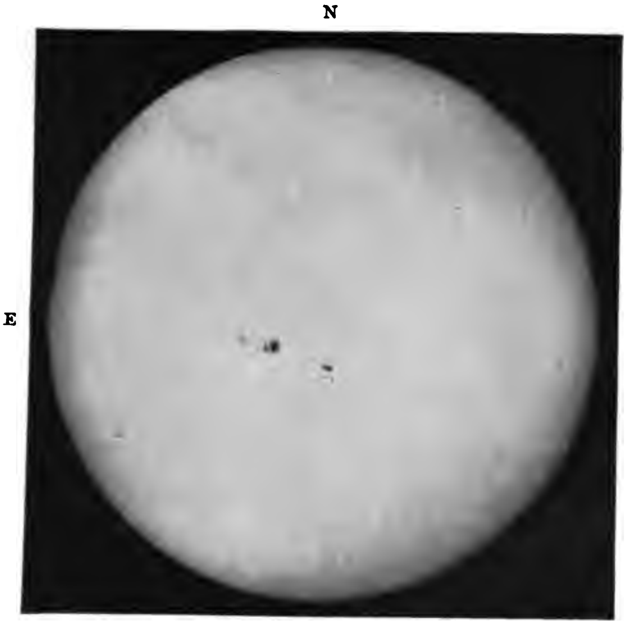

FIG. 1.—DIRECT SOLAR PHOTOGRAPH (SLOCUM).

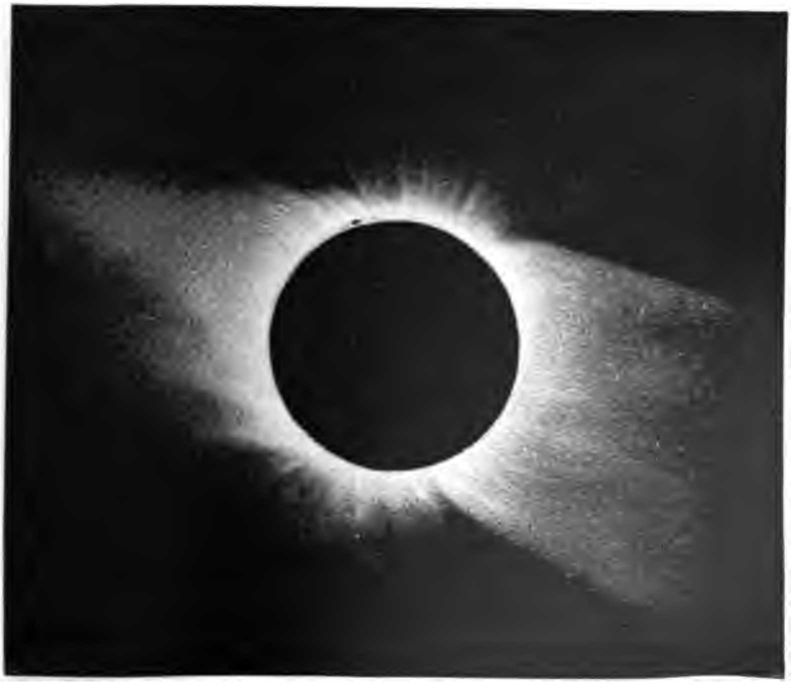

FIG. 2.—SOLAR CORONA, MAY 28, 1900.

(From drawing by P. R. Calvert from photographs by Yerkes Observatory Eclipse Expedition.)

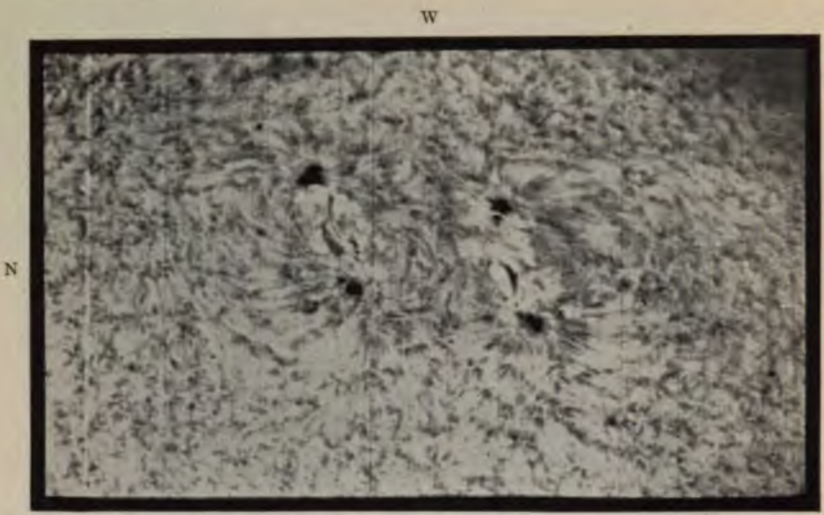

FIG. 1.—HYDROGEN SPECTROHELIOGRAM, Hα (ELLERMAN).

1909, September 10, G. M. T.; 3h 22m P. S. T.; 7h 22m A. M.

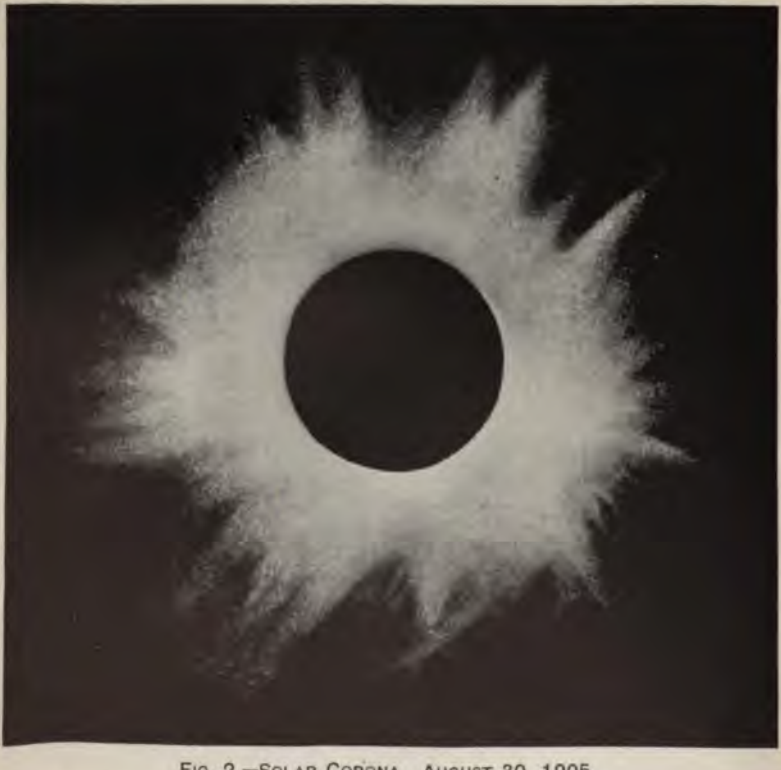

FIG. 2.—SOLAR CORONA. AUGUST 30, 1905.

(*From* drawing by Mrs. C. G. Abbot from photographs by the United States Naval Observatory Eclipse Expedition.)

magnetic declination and in the earth's magnetic force for the corresponding years. It will be seen how exactly the sun-spot curve is reproduced in these fluctuations of the earth's magnetism, but the cause of the connection which is so apparent is not yet well understood. In the upper curve of the figure are represented the departures of temperature for the average of 17 stations in the United States, and there will be seen, although not so plainly marked, an apparent influence of the sun spots on the temperature of the earth.

Recent work, much of it at the Mount Wilson Solar Observatory, has given us a good insight into the nature of sun spots. They appear to be whirls of material coming outward from the inner layers of the sun toward the surface, spreading out there like a waterspout. The expansion attending decrease of pressure on the gases causes a fall of their temperature, so that the sun spots are cooler than the surrounding parts of the sun, and this is the reason why they seem dark. The whirling matter contains electrical charges, which, by virtue of their rotation, give rise to magnetic fields, as shown long ago by Rowland. The presence of magnetic fields in sun spots has recently been established by Hale.

At certain times the moon interposes between the earth and the sun and cuts off the sunlight, so that we are able to see the objects which are surrounding the sun and usually lost by the intense glare of the sky. Such occasions are called "total solar eclipses." As the moon is but little, if at all, greater in angular diameter than the sun, the cone of shadow cast by the moon only a little more than reaches the surface of the earth, and sometimes, indeed, fails to reach it at all. When the cone reaches the earth's surface, and we have a total eclipse, there will be a belt, not more than 200 miles wide, but sometimes several thousand miles long, upon the earth's surface, in which the total eclipse may be observed at some time of the day. Frequently the belt of totality passes over inaccessible regions of the earth, as, for instance, the North or South Pole, or falls upon parts of the ocean where it is impossible to use delicate instruments. The longest possible period of totality at any one station is seven minutes, and in general the total eclipses average about three minutes in length Thus only a very little time can be used in eclipse observations, and yet the information to be gained at such times is so valuable that observers often spend months in preparation and travel thousands of miles to observe them.

Figure 2 of plates 1 and 2 show the total eclipse of the sun. The first is from a drawing of Calvert prepared from photographs by Yerkes Observatory observers at Wadesborough, N. C., in the year 1900, and the second is from a drawing by Mrs. Abbot from plates of the eclipse as photographed by the United States Naval Observatory parties in Spain and Africa in the year 1905. In each photograph will be seen the corona, so called, a pearly object stretching out in beautiful forms to a considerable distance outside the sun. A great change, however, apparently occurred in its form between the year 1900 and the year 1905. This change is shown by other eclipse observations to be characteristic, and to always accompany the change from sun-spot minimum conditions to sun-spot maximum conditions. At sun-spot minima the solar corona extends in long equatorial streamers, while at sun-spot maximum the corona, though somewhat brighter, is not so extensive in any particular direction, but stretches almost equally in all directions.

Close up to the border of the sun there are also seen, at times of solar eclipses, bright red flames, called prominences, which are due to the gases hydrogen and calcium, with sometimes an admixture of other chemical elements. These beautiful objects sometimes reach above the surface of the sun as much as 500,000 miles, and in some instances they have been observed to shoot up to such immense heights as this within 10 minutes of time. I say within 10 minutes of time, which implies that they may be seen at other times than during total eclipses. A method of observing them by aid of the spectroscope was devised independently by Lockyer and Janssen immediately after the eclipse of 1868, and nowadays many observatories examine them every day. A beautiful prominence is shown in plate 3 as photographed by Slocum at the Yerkes Observatory.

It would have seemed hardly credible to the contemporaries of Sir William, or even of Sir John Herschel, that the materials of which the sun and stars are composed could ever be known, but by aid of the spectroscope much is learned in this respect. White light may be thought of as a complex mixture of vibrations of the ether, so called; that medium which is supposed to fill all space, including the interstices between the atoms and molecules of material bodies. When light passes through a prism of transparent substance, the complex vibrations are decomposed into their component parts, and we see the spectrum, in which the colors are arranged in the order, violet, indigo, blue, green, yellow, orange, red. The spectrum is by no means limited by the end of the visible red, or by the end of the visible violet, for rays which may be photographed, and which produce heat when allowed to shine upon blackened substances, exist both beyond the red and beyond the violet. Those beyond the red are called infra-red, and those beyond the violet, ultra-violet. The ultra-violet rays may be readily photographed, and by specially staining photographic plates, with organic dyestuffs, it is possible also to photograph a limited region beyond the visible red. Further progress in that direction, however, must be made by delicate electrical thermometers or other heat-measuring instruments.

When the chemical element sodium or any of its compounds, like common salt, for instance, is placed in the flame, and the light which is given out is examined in the spectroscope, it is seen to consist of a couple of bright yellow lines. No general extension of the spectrum to include the green or violet is seen. On the other hand, if one observes the spectrum of the limelight or the electric arc from carbon poles, it is seen to give a long band of color much like the solar spectrum, except that, whereas in the solar spectrum a great number of dark lines are seen under good conditions, in the spectra of the arc light or of the limelight these lines will generally be absent. If, however, the vapor of metallic sodium be caused to intervene between the source of light and the slit of the spectroscope, two dark lines will be seen in the yellow, corresponding in position to the two bright yellow lines which are found by observing the light from heated sodium, or heated common salt. In short, the yellow light is absorbed by the sodium vapor at the very positions in the spectrum where that vapor would itself give off light if strongly heated. The same is true of iron and other metals. The spectrum of iron is very complicated, consisting of a great number of lines, many of them in the green. If the arc light be caused to play between iron poles, these bright green lines will be the main features of the light as observed in the spectroscope. Some of these lines are very strong, others quite weak, so that there is often a well-marked distinction between one line and another, not only as regards its place but also as regards its intensity in the spectrum.

Now, it is found on observing the spectrum of the sunlight or starlight that the dark lines are found in the same relative positions, and generally of nearly the same relative intensity, as in the bright line spectrum of the chemical elements themselves. In this way it is possible to determine what elements are found in the sun and the stars, although these bodies are so immensely distant from us. In this way we know that more than 40 of the ordinary chemical elements found upon the earth exist also in the sun, and the existence of about 20 more is doubtfully indicated by the solar spectrum. Not only does the approximate correspondence in position and intensity of the spectrum lines of the sun and of the chemical elements as observed in the laboratory yield this significant result, but the slight deviations from exact correspondence in intensity and in position of the spectrum lines yield other facts not less remarkable. For instance, it was predicted by Doppler and observed in the laboratory by Prince Galitzen that the motion of a source of light toward the observer displaces its spectral lines toward the violet, and, contrariwise, the motion of the source of light away from the observer displaces the spectral lines toward the red. This effect is very noticeable in the solar spectrum if one takes the light from the east and west limbs of the sun. There is a displacement of the lines of the two spectra with respect to one another, depending upon the fact that the one side of the sun is approaching the earth and the other side receding, by virtue of the rotation of the sun on its own axis.

It had long been known that the sun rotated upon its axis, because of the behavior of sun spots, which march across the disk of the sun in a period of about 14 days.[1] Duner, Halm, Adams, and others have observed the rotation of the sun by means of the displacement of the spectral lines. The curious fact that the surface of the sun rotates with unequal velocities, largest at the equator and smaller as we approach the poles of the sun in either direction, had been noted from sun spot observations. This peculiar rotation behavior of the sun's surface was investigated much more thoroughly by Adams, who followed the rotation of the sun up to solar latitude of 75°. He found that the period of rotation, as determined by the majority of the spectrum lines, varied from 24.6 days at the equator to 33.1 days at latitude 75°. However, the element hydrogen, which is situated high up in the solar atmosphere, indicated a much more nearly equal velocity of rotation at differing latitudes. The values range from 23.7 days at the equator to about 26 days at latitude 75°.

Another cause of the displacements of the spectral lines is in the pressure which exists in the solar envelope. This was investigated first by Humphreys and Mohler at Baltimore. It has since furnished a valuable means of measuring the pressure which exists in the solar envelope. For the element iron it is found to be about five times the atmospheric pressure at the surface of the earth.[2]

Still another interesting displacement of spectral lines was found by Zeeman to be due to the presence of a magnetic field. Spectrum lines are broken up in the presence of a magnetic field into doubles or triples or still more complex groups, whose complexity of arrangement depends upon the situation of the spectroscope with respect to the magnetic field, and on the strength of the magnetic field in which the light is produced. This peculiarity was taken advantage of by Hale, who has recently proved the existence of a magnetic field in sun spots, and still more recently the existence of a general magnetic field over the whole surface of the sun, analogous in many respects to the magnetic field which exists over the surface of the earth.

A brilliant invention of Hale's earlier years of investigation was that of the spectroheliograph. This is an instrument for observing the sun's disk in the light of a single line of a single chemical element.

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[1] This exceeds the half-period of the sun's rotation because of the advance of the earth in its orbit at the same time.

[2] Recent work of Evershed and of St. John indicates that this estimate must be revised, and that pressures of one atmosphere or less exist where the iron lines are formed.

It is not necessary here to explain the details of the construction or the principle of it, more than to say that it is a particular form of spectroscope whose effect is to act as a screen to cut off all rays of the spectrum except the particular one which it is desired to observe. By the aid of this instrument the distribution of the gases of different elements over the sun's disk has been investigated, notably of the gases hydrogen and calcium. Plate 2, figure 1, shows a photograph of a portion of the sun's disk as observed in hydrogen. The reader will note the very prominent detail which is shown by this illustration as compared with that shown by direct photography of the sun's surface by a telescope as given in plate 1, figure 1. It was by the aid of the spectroheliograph that Slocum obtained the beautiful figure of the solar prominence given in plate 3.

SOLAR ENERGY.

We now turn from this general consideration of what may be seen on the sun by the aid of the telescope and spectroscope to a discussion of the quantity of energy which the sun sends out, the distribution of it among the different spectrum rays, and the relations which it bears to the temperature of the sun, the temperature of the earth, and other terrestrial concerns. I said a little while ago that light is regarded as of the nature of a mixture of vibrations in the ether, which is supposed to be a substance existing in all space, including the interstices of the structure of the chemical elements themselves. Light is but one of the manifestations of radiation. It is merely that kind of radiation which is visible to the eye. Just as there are some sounds which are of too high pitch for the ear to hear, and some other sounds which are of too low pitch to distinguish as sound, so there are kinds of radiation which are of too short wave length for the eye to recognize as violet light, and others are of too long wave length for the eye to recognize as red light. Indeed for the longer wave lengths of radiation the substances of the eye are not transparent, so that even if the retina should be sensitive to these rays, they could not reach the retina to affect it.

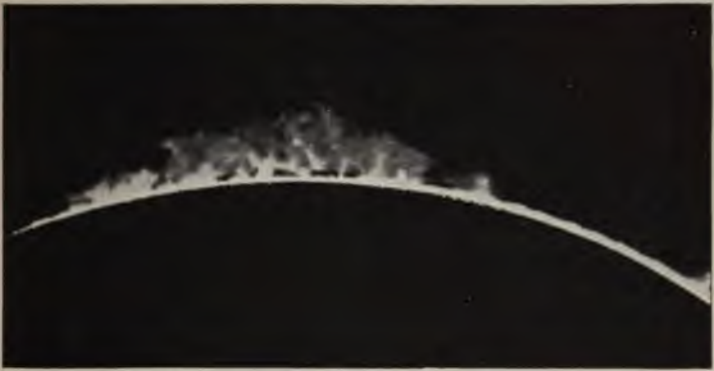
In this state of affairs it is necessary to proceed to the investigation of the energy of radiation by means of another instrument in which the radiation is caused to be absorbed by a blackened surface, and thus to produce heat, and consequently a change of temperature of the absorbing substance. Radiation is not heat. Heat is a motion of the molecules of the material substance, but radiation is a motion of vibration in the ether, which is not regarded in the same category with ordinary chemical elements. Indeed, we may go a little further and make a classification of energy. Imagine a chest of drawers in which, as sometimes happens, the letters or other papers fall over the back of the drawers, as they are pulled out into the ones below. It is easy in that manner for the papers in the upper drawers to fall into the lower drawers, but work has to be done in order to get the papers from the lower drawers into the upper ones again. So with energy—all forms of energy may easily be transformed into heat, which is the lowest type of energy, but heat energy can only partially be transformed back again into the higher types. Of these types radiation is one of the very highest.

Now it is on the sun's radiation that a temperature suitable for life upon the earth depends. Not only that, but the peculiar properties of certain wave lengths of the solar radiations are required for supporting plant growth, with its complex chemical reactions. All sources of energy upon the earth have been directly or indirectly produced by solar radiation. A good many investigators, among them Mr. Shuman, of Philadelphia, have endeavored to use the solar radiation commercially for the production of power, and, in fact, very satisfactory results are being obtained in this way, under Mr. Shuman's direction, from a plant in Egypt.

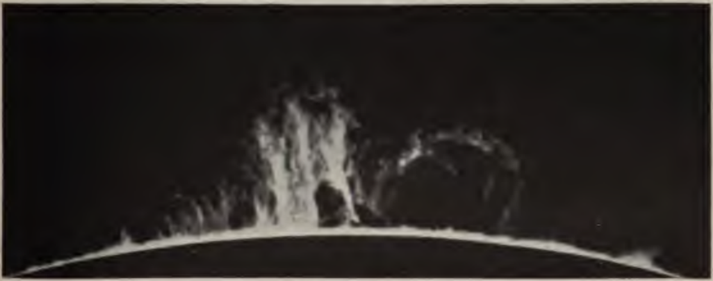
Evidently it is of the greatest interest to measure the quantity of the solar radiation, the distribution of it in the spectrum, the hindrances which it suffers in passing through the earth's atmosphere, and the quantity of it available to warm the earth after it reaches the surface. This has been the principal work of the Astrophysical Observatory of the Smithsonian Institution for the last 12 years.

In the first place, we have to deal with the measurement of the solar radiation as a whole. For this purpose we employ what is called the pyrheliometer, a name first devised by Pouillet, about the year 1835. He employed a blackened box, filled with water, and containing a thermometer for observing the rise of temperature in the water due to the absorption of the solar rays upon the blackened box. In our practice we have considerably developed the instrument of Pouillet, until now it comprises a silver disk inclosed in a chamber provided with a vestibule for the admission of the solar rays. The disk has inserted in it a thermometer, which is bent at right angles for convenience, and on which the rise of temperature of the silver disk due to the absorption of solar radiation is observed. The instrument is shown in figure 2.

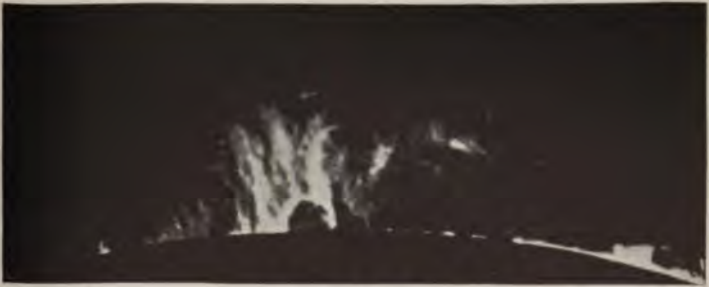
It is not possible to obtain the correct heat capacity of the pyrheliometer in this form, so that we have reduced its measurements by comparison with what is termed the standard pyrheliometer, in which the heat produced by the sun's radiation is carried off by flowing water. The rise of temperature in the water, due to the absorption of the solar radiation, is determined by means of an electrical thermometer. In this apparatus it is possible to introduce electrically known quantities of heat, and to measure them as if it



1910, March 17, G. M. T.; 5^h 30^m; long. 7°; lat. +17° to −18°.



1910, October 10, G. M. T; 7^h 56.8^m.



1910, October 10, G. M. T.; 8^h 6.4^m.

SOLAR PROMINENCES (SLOCUM). CALCIUM (H) SPECTROHELIOGRAMS.

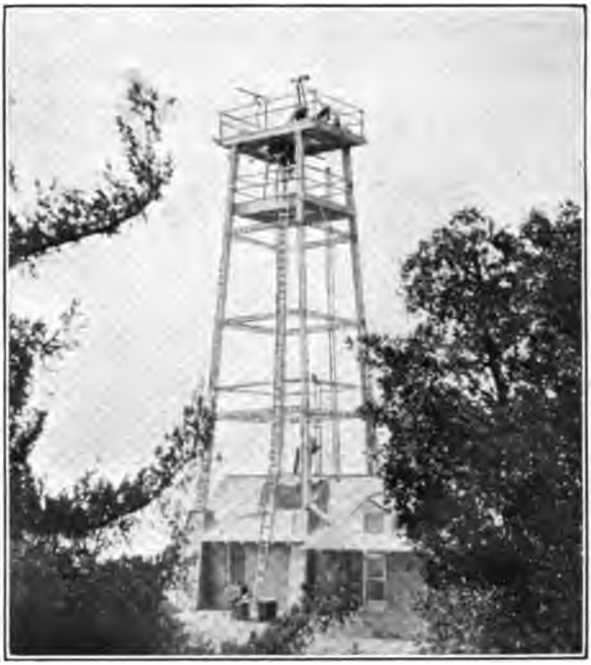


FIG. 1.—SMITHSONIAN OBSERVATORY ON MOUNT WILSON.

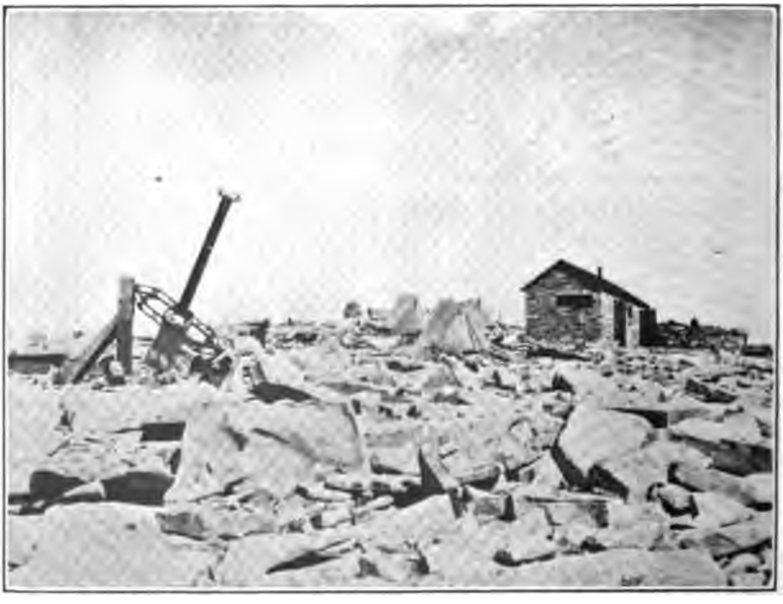


FIG. 2.—SMITHSONIAN OBSERVATORY ON MOUNT WHITNEY.

were solar radiation which was being measured. In such test experiments it is found that as much as 99 per cent of the heat introduced is recovered, and it is believed that the standard pyrheliometer gives the true scale of radiation for the sun within a probable error of a half of 1 per cent. The silver disk pyrheliometers have been compared with this standard, and in this way the standard scale of radiation has been diffused by the Smithsonian Institution, which has sent out about 25 copies of the standardized silver disk pyrheliometer to various countries of the world, in Europe and North and South America.

Measurements with the pyrheliometer indicate that the maximum intensity of the sun's radiation at sea level is about 1.5 calories per square centimeter per minute. At high-level stations, such as Mount Whitney, in southern California, at an altitude of 14,500 feet, the readings run as high as 1.7 calories per square centimeter per minute. You may ask why it is that if the intensity of the sun's radiation increases as we go up a mountain, it should be also the case that the temperature of the air at high elevations is lower than it is at sea level. This is due to the property of the air of almost freely transmitting solar radiation. Like a pane of glass in a window, it is not much warmed by absorbing the rays, whereas a blackened substance held in the beam of light, either upon a mountain or inside the window pane, will be very appreciably warmed.

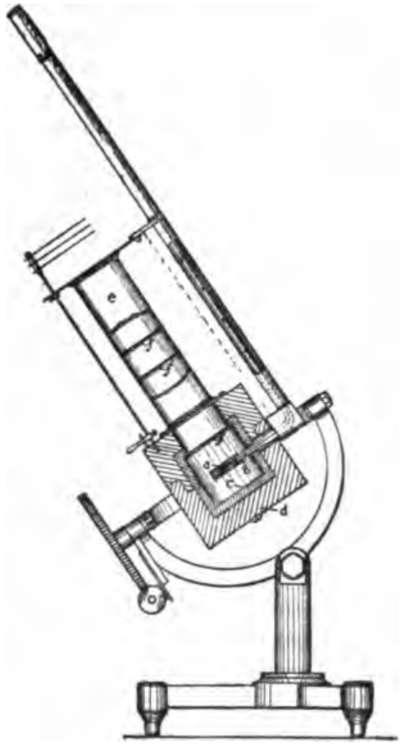


FIG. 2.—Silver disk pyrheliometer.

If we could go outside the atmosphere altogether, all the radiation which we receive from the whole sky, and which is derived by scattering, would be still in the direct sun-beam. Looking away from the sun we should see the stars shining, as if at night, and the sun's rays themselves as observed by the pyrheliometer would exceed in intensity even those observed on high mountain summits. Now the question is, what would be the intensity of the solar radiation if we could observe it outside the atmosphere, at the earth's mean solar distance? This quantity is called the solar constant of radiation, and it has been an object of investigation for the last hundred years.

As shown by Forbes, Radau, and notably by Langley, it is not possible by means of the pyrheliometer alone to estimate what the intensity of the solar radiation outside the atmosphere would be, unless the pyrheliometer itself could be raised by a balloon or otherwise to the extreme limit of the atmosphere. This latter procedure having heretofore been impracticable,[1] it was necessary to have recourse to measurements of the solar spectrum. The defect in pyrheliometer observations consists in this: That the several rays of the solar spectrum are unequally affected in passing through the earth's atmosphere. Certain rays are almost completely removed in the higher levels of the atmosphere, so that we can by no means estimate the losses, even upon the highest mountains, unless recourse is had to determinations in the spectrum.

About the year 1880 the late Dr. Langley invented the bolometer. This is an electrical thermometer of great sensitiveness. It comprises two fine strips of platinum, each about one-half inch long, one two-hundred-and-fiftieth of an inch wide, and one two-thousandth of an inch thick. The strips are blackened on the front surface with smoke, or with platinum-black electrically deposited. These two strips, with two coils of resistance wire, form a Wheatstone's bridge, so called. If one strip is warmed with respect to the other, and thereby its electrical resistance is increased, the effect is to cause a slight current of electricity to flow through a very sensitive galvanometer. In ordinary practice one can detect with the bolometer differences of temperature of a millionth of a degree; and in the most refined construction, with every precaution taken to avoid disturbing influences, it has been possible to observe the hundred-millionth part of a degree change of temperature.

With the bolometer, which in those days was an instrument of very uncertain behavior, and one requiring the most expert attention and great patience for its use, Langley observed the sun's spectrum in the famous expedition of 1881 to Mount Whitney, in southern California. Like early investigators who had used the pyrheliometer alone, he observed the increase of the intensity of the sun's rays from early morning to noon, and their decrease of intensity from noon until late afternoon. This depends, as you will see, upon the fact that when the sun is low and near the horizon its rays shine obliquely through the atmosphere, so that their path in the air is very long, whereas at noon, when the sun is nearly overhead, the path in the air is comparatively much shorter. If one observes, therefore, the intensity of each of the spectrum rays at different altitudes of the sun, for which he knows the length of path in air, he may compute from the observed increase of intensity, attending the decrease of air path, how much the intensity would be if the path in air could be reduced to nothing at all, or, in other words, if he could go outside the air altogether. It is not possible to do this by observation with the pyrheliometer alone, as explained above, because the rays of certain spectrum wave lengths are almost entirely removed in the upper atmosphere, and do not reach the observer at all, even if he be on a high mountain. Especially is this the case in the infra-red region of the spectrum, which is invisible to the eye, but which is of great importance as containing a large part of the sun's energy. In this region there are great water-vapor bands, where the water vapor of the atmosphere almost completely absorbs the solar rays, leaving great gaps in the representation of the sun's energy spectrum. Langley introduced the procedure of estimating for all other parts of the spectrum the intensity which would be found outside the atmosphere, but in the great water-vapor and other terrestrial bands of absorption he merely made the assumption that these would be altogether absent if he could in fact be beyond the atmosphere altogether.

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[1] The author has recently devised apparatus which has recorded solar radiation successfully at enormous altitudes. The results confirm those given below.

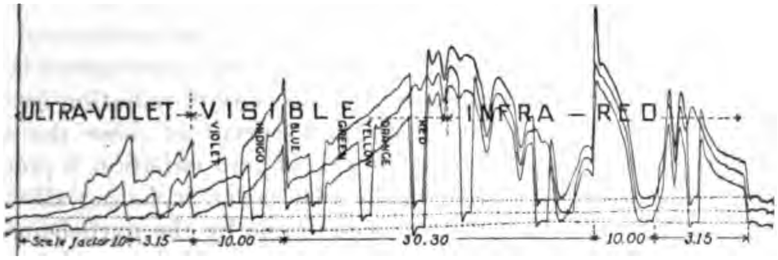

FIG. 3.—Bolographs of the Solar Spectrum. Air masses of observation: Upper curve, 3.0; middle curve, 4.0; lower curve, 5.2.

After Langley became Secretary of the Smithsonian Institution he established the Astrophysical Observatory there, in order that he might carry out to greater perfection the measurements of radiation begun by him while still director of the Allegheny Observatory in Pennsylvania. Among the first improvements introduced in Washington was the automatic recording of the results of the bolometer by photographic means. This was a great step, so that now we are able, in the lapse of less than 10 minutes, to observe the intensity of the rays of the sun of all wave lengths, from those far beyond the violet end of the visible spectrum to those far beyond its extreme red. Figure 3 shows the result of three such observations made on Mount Wilson, in California, at the station of the Smithsonian Institution there. These three curves represent the distribution of solar radiation in its spectrum, including the ultra-violet, visible, and infra-red rays. The great water-vapor bands above mentioned are shown in the infra-red as great depressions of the curve. Solar absorption lines are shown in the visible spectrum as smaller depressions of the curves. The three curves were taken at different hours of the morning, when the path of the solar rays in air was five, four, and three times, respectively, that which would occur if the sun were vertically overhead. The reader will notice that the curves are respectively higher and higher, especially in the violet end of the spectrum, owing to the decrease of the length of path of the sun rays in the air. At several points a change of scale of the curves is shown. This is due to the introduction in the beam of rotating sectors of different angular apertures in order to keep the record always within the limits of the registering photographic plate. If these changes of scale had not been made, the curve would run up in the edge of the red to the height of several feet.

By suitable computation, by the aid of the exponential formula developed by Bouguer about the year 1760, it is possible to compute for each of the parts of this spectrum energy curve the intensity which would be found if one were outside the air altogether. In this way one might construct a curve similar to the three shown in the illustration, which would represent the intensity of radiation beyond the limits of the atmosphere. In such curves as these the area included between the curve and the axis of zero radiation is proportional to the intensity of the whole solar beam, including all wave lengths. This, of course, is also measurable by the pyrheliometer. Accordingly we multiply the reading of the pyrheliometer by the ratio between the area of the curve outside the atmosphere and that which is found at the observing station, and thereby we obtain the solar constant of radiation. In this process, however, we follow Langley's assumption that there will be no absorption by water vapor or oxygen in the sun itself, and therefore draw a smooth line in our extra-atmospheric energy curve, where great atmospheric bands occur.

About 700 determinations of the solar constant of radiation have been made by the Astrophysical Observatory of the Smithsonian Institution, some at Washington, at sea level; others at Mount Wilson, at an elevation of about 1 mile above sea level; others at Mount Whitney, at an elevation of nearly 3 miles; and others at Bassour, Algeria, at an elevation of three-quarters of a mile. No differences beyond the reasonable errors of measurement are found between observations made at two stations on the same day, whether made at sea level or at any of these stations, up to the elevation of Mount Whitney, 14,500 feet above sea level. Hence it appears that the method of estimating atmospheric transmission is probably sound. The mean value of the solar constant of radiation, as thus found from 700 determinations, is 1.933 calories per square centimeter per minute. By this is meant that if the sun's rays outside the atmosphere could be absorbed completely in a layer of water 1 centimeter (about three-eighths of an inch) thick, exposed at right angles to the solar beam, this layer of water would be warmed 1.93° C. during each minute of time. Expressed in another way, the sun's radiation outside the atmosphere would be able to melt a layer of ice 105 feet thick each year.

An extremely interesting feature of the measurements has been that they show a variation of the sun. This conclusion has been tested in every way, not only by making measurements at different altitudes but by comparing results obtained on the same days at Mount Wilson, in California, and at Bassour, Algeria. As these stations are separated by about one-third the circumference of the earth, it seems not possible that they could be generally influenced by local conditions in a way to disturb the measurements in the same direction at the same time. Nevertheless, the results of about 50 days of simultaneous observing at the two stations agree in showing that when the radiation of the sun is found above the normal at the one station it is found also above the normal at the other station, and vice versa. The fluctuations of the intensity of the sun's radiation outside the atmosphere thus indicated range over about 10 per cent. Often within a single week or 10 days a fluctuation of radiation as great as 5 per cent is shown. The variation of the sun in these short periods appears to be irregular, both as regards the magnitude of the variation and as regards the period of it.

The measurements made at Mount Wilson, which extend over the years 1905 to 1913, indicate also a fluctuation of the intensity of solar radiation, attending the changes of the number of sun spots. There appears to be about 3 per cent increase of the solar radiation outside the atmosphere for an increase of 100 in the Wolf sun-spot numbers. It is a very curious thing that the solar radiation increases with increasing numbers of sun spots, whereas the temperature, which directly depends upon the solar radiation, falls with increasing numbers of sun spots. It appears that there is attending sun spots a direct and an indirect influence on terrestrial temperature. The direct influence is due to the increased solar radiation. The indirect influence is perhaps due to a change in cloudiness, but as yet is not certainly understood. These two influences are of almost equal magnitude in general, but with the indirect influence, which tends to lower temperatures, slightly predominating. It will be a research of great interest and value to determine the cause of the indirect influence.[1]

In connection with these researches on the solar radiation the transparency of the air for light of all colors and for invisible rays has been determined. This is a matter of great interest to those who are studying the growth of plants, as well as to those who are interested in the propagation of signals by means of lights at sea and elsewhere.

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[1] The author is informed that researches by the meteorological service of India indicate that not all stations of the world are cooler at sun-spot maximum.

Also, the form of the energy spectrum of the sun having been determined, it is possible to estimate the probable temperature which exists in the sun. For it is shown that as the temperature of a source of light increases, the position of the wave length of maximum intensity in its spectrum shifts toward the violet end of the spectrum, and from the exact position in the spectrum of the wave length of maximum intensity the temperature of a source of light may be ascertained. In this way it appears that the sun's temperature is of the order of 6,000° C., or nearly twice the temperature of the arc light. It is also possible, by means of the measurement of the solar constant of radiation, to determine the sun's temperature. In this way also values of the order of 6,000° C. are found.

The surface of the sun is not equally bright from one edge to the other. This is shown plainly on solar photographs, as was pointed out in relation to plate 1, but a more careful study of the matter is being made by the Astrophysical Observatory of the Smithsonian Institution, at its station on Mount Wilson, by the aid of the bolometer. Plate 4, figure 1, shows the observing station of the Astrophysical Observatory, and the reader will see a tower which has been erected upon it, in which is a vertical telescope for forming a large image of the sun. By stopping the clockwork, this image is allowed to drift across the slit of the spectro-bolometer. Thereby an automatic record is produced of the distribution of radiation of any selected wave length from one edge of the sun along the diameter to the opposite edge. Such observations are shown in figure 4. The distribution of radiation is given for five different wave lengths.

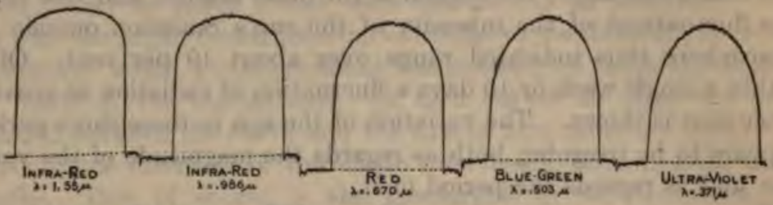

FIG. 4.—Brightness distribution along sun's diameter for different colors.

It is seen that there is a marked contrast of brightness, espe [illegible] for violet rays. Here the edge of the sun's disk is h [illegible] bright as the center. The contrast of bri [illegible] increasing wave length of the light ex [illegible] rays is comparatively small. Experim [illegible] day on which the solar constant of rad [illegible] to see if there is a change of contrast i [illegible] of the sun, accompanying the change of the intensity of the sun's radiation. Changes of contrast along the sun's diameter have already been found, but it is not yet decided whether they agree in point of time with the changes in the intensity of the solar radiation.[1]

NATURE OF THE SUN.

In view of what has been said, what is the nature of the sun? It appears, in consideration of its high temperature and low density, to be a great ball of incandescent gases. Of course, the pressure is so enormous that the gases approach the density of liquids. These gases are so hot as to exceed in temperature anything that we have upon the earth's surface. It must not be supposed, however, that they are burning gases like the burning of illuminating gas in air. The temperature on the sun's surface is so high that in general no compounds of elements are occurring there. If the ordinary compounds, for instance, products of combustion like carbonic-acid gas, should be present on the sun, the elements of which they are composed would separate, one from another, owing to the enormous temperature. As the sun gives off radiation, it tends to cool, and it may well be asked why, in the course of the millions of years which geologists tell us have elapsed since the earth reached substantially its present temperature, the sun should not have cooled off entirely. A partial source for this immense quantity of energy was suggested by Kant and discussed at length by Helmholtz, who showed that the enormous gravitation of the sun, tending to condense the gases and bring them toward its center, must, for every decrease of temperature and consequent shrinking up of the volume of the sun, produce a certain quantity of energy. This source of the sun's energy, however, seems insufficient to account for that which geologists demand us to concede. It may be that the secret of the matter is in the breaking up of the atoms, such as is now found to occur with the element radium.

If the sun is gaseous, the question naturally arises why it presents so sharp and round a boundary. The roundness of the sun is only what would be expected in view of its gravitation. The sharpness of its boundary seems explainable as follows: Gases, although very transparent, are not perfectly so, so that in the case of the earth the atmosphere above Mount Wilson transmits only about 95 per cent of the yellow light. If, then, 5 per cent of the sun's radiation in the yellow is cut off by the earth's atmosphere, it follows that a layer of the sun's gases only a few thousand miles thick would be sufficient to prevent us from seeing any deeper. This 3,000 or 4,000 miles of thickness, as we look at the center of the sun, will extend vertically downward, but at the edge of the sun we look obliquely, and there the 3,000 or 4,000 miles will all be found in a layer of the sun perhaps not more than 100 miles in thickness. In a body 800,000 miles in diameter a thickness of 100 miles is practically negligible, certainly so for any telescopic observations which can be made from the earth, hence, naturally, the boundary of the sun is seen to be sharp.

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[1] Experiments of 45 days in 1913 indicated that there is such agreement in point of time. Thus the variability from day to day is again independently confirmed.

The contrast of brightness between the center and the edge of the sun follows at once from what has just been said. For at the center we look far deeper than at the edge, and, naturally, see thereby gases which are much hotter than those which are perceived in the comparatively superficial layer which is seen at the sun's edge. Attending the increase of temperature there must be an increase of brightness, and this will be greater for red and infra-red rays than for violet and ultra-violet rays, in accordance with laboratory experiments on the relations of radiation and temperature. Thus the contrast of brightness between the center and the edge of the sun will be greater in the red and infra-red than in the violet and ultra-violet.

The sun spots appear to be whirlpools where the gases of the interior are pouring out toward the exterior in forms similar to a waterspout. They are cooled by expansion as they reach the surface, and the partial vacuum formed in the center of the whirl sucks in the superincumbent and very light gases, hydrogen and calcium, above the sun's surface. The magnetic field found by Hale in sun spots is due, no doubt, to the rotation of the electrically charged material in the spots. The solar spectrum, with its numerous dark lines, is due to the presence of the gases of the chemical elements which are found upon the earth. These gases are cooler at the boundary of the sun than they are within, where the principal part of the light comes from, hence, as noted above, the effect will be to produce dark lines on a bright background. The irregular mottled appearance of the sun's surface is probably due to differences of temperature which exist in so great a body, and thereby produce variations in brightness of different parts.

It is impossible to go further and touch upon the very interesting questions connected with the sun's place among the stars, the dependence of plant growth upon solar radiation, and the relations between the temperature of the earth and the radiation of the sun. These matters, and many details, which it has been impossible to mention in this short account, are discussed by the writer in a book entitled "The Sun," to which and to the original sources of information and to longer treatises the interested reader is invited to turn.

MODERN THEORIES OF THE SUN.[1]

By **Jean Bosler**,

Astronomer at the Meudon Observatory.

[With 2 plates.]

It is the sun alone among all the stars that we can ever hope to see in detail. It alone can aid us in understanding all the others and throw light on their evolution. Furthermore, whatever our ideas may once have been, they had no solid experimental basis until the invention of the spectroscope toward the middle of the last century. This remarkable discovery taught us that there was something further to observe in the sun than the spots, the faculæ, and the prominences visible at the eclipses; the appearance of these phenomena to the eye has therefore lost something of the exclusive interest it formerly usurped. The Janssen-Lockyer method of utilizing the monochromatic hydrogen light from the prominences had already enabled us to see them at any time on the limb of the solar disk. The spectro-heliograph, based upon a bold and ingenious generalization of analogous principles, now reveals to us in the flocculi (pl. 2, fig. 1), the filaments and alignments (pl. 2, fig. 2), new phenomena formerly invisible which, perhaps, equal or even surpass in importance the spots and faculæ. It is on these new appearances that the interest of the present-day astronomer is especially centered.

Our knowledge of the constitution of the sun is naturally increased by all this progress. The fact that the solar spectrum is made up of black lines upon a bright continuous background shows, according to Kirchhoff's law, the existence of a very hot source of light surrounded by a cooler absorbing layer of gas. The latter produces in the spectrum the lines of a great number of terrestrial substances—iron, hydrogen, calcium, magnesium, sodium, etc. Its inner portion, situated close to the brilliant *photosphere*, has been called the *reversing layer*. It contains the heavier elements, while the outer layer or *chromosphere* contains principally hydrogen and calcium. Farther out yet, extending a distance of several solar radii, is found the *corona* which we have not yet succeeded in observing except at total eclipses of the sun (pl. 1).

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[1] Summary of two lectures delivered Apr. 11, 1913, and Jan. 9, 1914, at the observatory of the Société Astronomique de France. Translated by permission from L'Astronomie, 28th year, February, 1914, Paris.

PHYSICAL CONDITION OF THE SUN.

Formerly the continuous background of the solar spectrum was attributed to an incandescent solid or liquid nucleus. The prevalent theory at present is that the sun is entirely gaseous. For this belief there are several good reasons: Apart from the mean low density of this star (1.4 relative to water), its temperature is, as we shall see, higher than that at which all known bodies volatilize. Further, a sphere not gaseous but solid or liquid would near its edge emit polarized light, of which we observe not a trace. Finally, the way in which the sun rotates is in complete contradiction to a rotating rigid solid body. The objection based upon the continuous background of the spectrum alone remains. This was overcome when it was found that gases can give such a spectrum. The bright lines in the spectrum of a gas are narrow and separate when the gas is under a weak pressure, but they broaden as soon as the pressure is increased, and, finally, a continuous background appears which may indeed become very bright.

We find, therefore, that in order to account for the observed facts it is sufficient to assume that the heavy vapors gather at the center, where they are under great pressure, while, according to their densities, the lighter gases in successive layers make up the outer portions. This explanation, however, has not satisfied all, and physicists ask whether the great diffusive tendencies in a gas would not finally tend to transform the whole mass into a perfectly homogeneous mixture. Further, the form of the sun, so perfectly round and, moreover, so sharp, requires an explanation which the laws of refraction for a moment seemed to give and about which we will say a word.

We know that in our own atmosphere the path of a beam of light is curved by refraction, especially when the beam is near the horizon. (Fig. 1.) Now we may conceive (theory of Schmidt) that the law of densities in the sun's atmosphere is such that, when the beam of light is sufficiently inclined to the vertical, the path is so curved that it never leaves the sun. (Fig. 2.) On such a star, in the upper very rare layers, everything would appear as on the earth; in the lower layers, however, only those rays near the vertical would succeed in escaping. These two regions would evidently be separated by another where the luminous trajectories would encircle the star many times before emerging. (Fig. 3.) It is this very thin layer which, according to Schmidt, constitutes the photosphere. Further, the dark lines of the spectrum may be explained by the optical

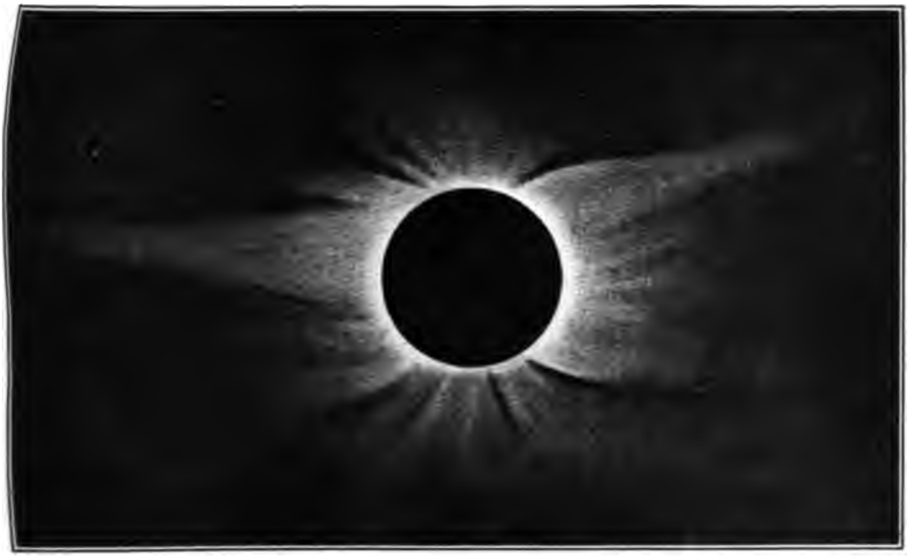

FIG 1.—SOLAR CORONA: ECLIPSE OF MAY 28, 1900 (PERIOD OF MINIMUM ACTIVITY).
Drawn by M. W.-H. Wesley, from photographs by M. Maunder.

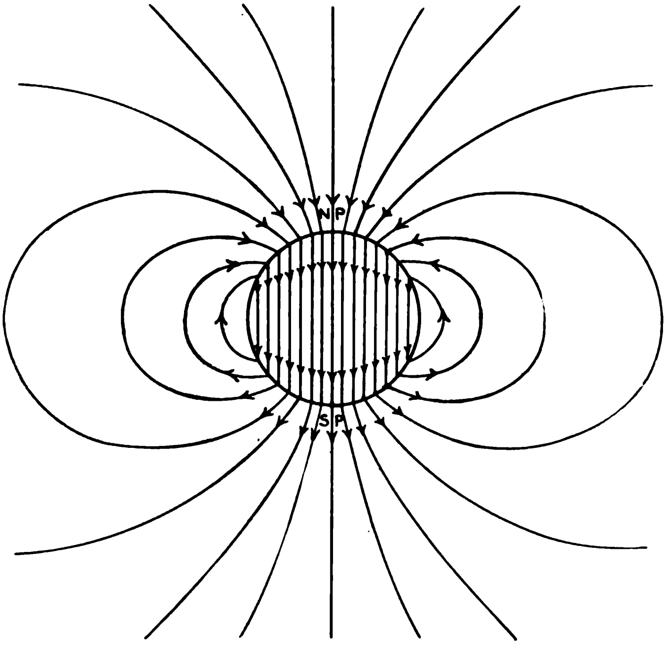

FIG. 2.—LINE OF FORCE OF A SPHERE UNIFORMLY MAGNETIZED.

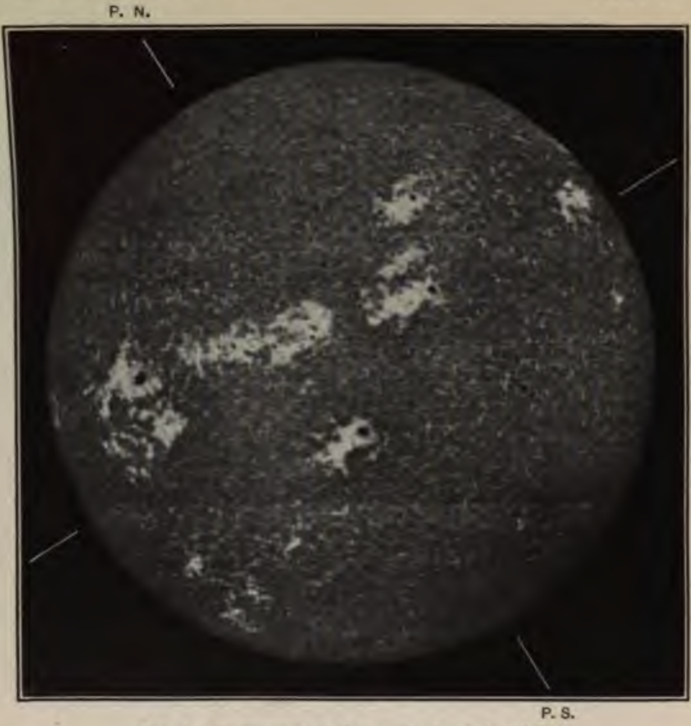

FIG. 1.—FLOCCULI OF CALCIUM, JULY 1, 1906.

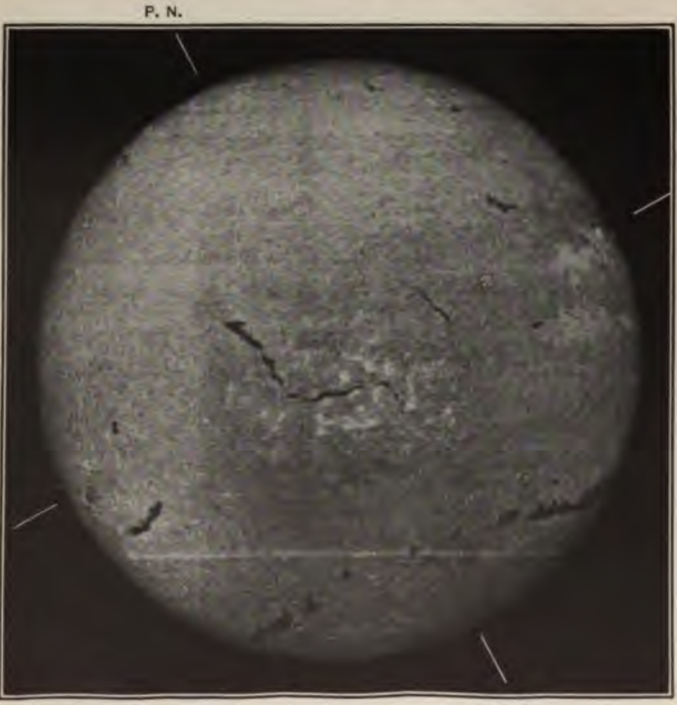

FIG. 2.—FILAMENTS AND ALIGNMENTS OF HYDROGEN, APRIL 11, 1910.

Photographs of the sun, taken with spectroheliograph.

phenomenon of anomalous dispersion,[1] which accounts also for the winged appearance of their edges (Julius). This same theory offers also an explanation of the divers aspects of the chromosphere, the flocculi, the prominences, as well as, though less satisfactorily, the spots.

All that is very ingenious. Unfortunately this explanation of the photosphere assumes that there is no absorption of light in the sun. Further, the lines of the spectrum produced by anomalous dispersion should be unsymmetrical, and they are not. Although some physicists remain faithful to these new theories resting on anomalous dispersion, fascinated by their elegance, astronomers who actually see the sun and observe the effects due to perspective can not believe in such a great optical delusion. They therefore generally cling to those ideas which were held in the first place and which have become classical.

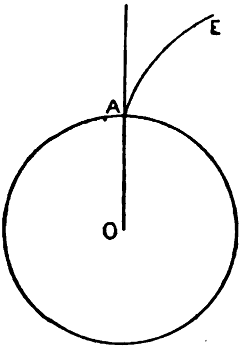

FIG. 1.

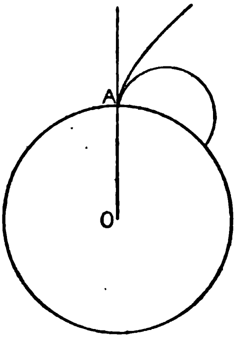

FIG. 2.

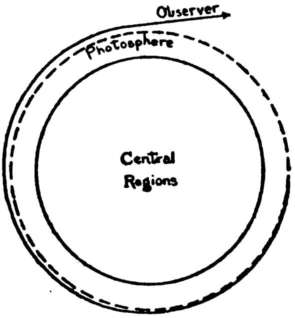

FIG. 3.

SOLAR HEAT.

Our ideas as to the temperature of the sun remained for a long while in an unsatisfactory state until science made the decisive step which was to insure a good solution. We can not tell the temperature of a body at a distance except by means of some hypothesis as to the emissive power of its surface. But we may agree to call the *effective temperature* of a distant body that of a "black body" having by definition a maximum emissive and absorbing power at all temperatures and which, if situated at the same place, would send us the same amount of heat.

The theoretical and experimental study of "black bodies" has shown that their radiation is proportional to the fourth power of their absolute temperature (Stefan's law). This leads us to measure the amount of heat per unit time and unit surface which the sun sends us—that is, the "*solar constant.*" It is about 2 small calories per square centimeter per minute and corresponds to an effective temperature of a little less than 6,000 degrees absolute (Centigrade). Another method based upon the wave-length of the most intense radiation in the solar spectrum (Wien's law), always assuming an emission from a black body, leads to a like result.

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[1] We can not here enter much into details, for which we must refer the reader to special treatises on the sun.

This is very far, as you see, from the millions of degrees formerly supposed. It does not mean, however, that the heat sent out from the sun is not enormous. We may well ask by what means this immense loss of energy is compensated. It is indeed impossible that the sun should burn like an immense block of coal. The most intense combustion revealed to us by the chemist, for example, that of gun cotton, would not suffice to feed this radiation for more than a few thousands of years. We must look elsewhere. A rain of asteroids has been suggested, which by its kinetic energy would restore the lost heat to the sun. Such an hypothesis is not possible. The mass of the sun would increase indefinitely and the planets should show an unobserved acceleration. The sun, however, as Helmholtz supposed, could contract little by little, changing into heat the internal energy of the primitive nebula of Laplace. A contraction of 30 meters per year would suffice to explain all. Unfortunately, a very suggestive calculation shows that all the heat that the sun could thus develop since its origin, *by any mechanical process whatever*, would not sustain the radiation for more than 15 million years. And the world is very much older than that, at least so the geologists affirm. Their arguments, taken separately, do not seem without value; but what is more remarkable, they all tend, by different paths, to lead us to admit a past very much longer than 100 million years, figuring perhaps into thousand millions. We must apparently search in the interior of the atoms themselves for the source of the solar heat. The infinitely small, as Pascal said, will explain the infinitely great.

The intraatomic energy is indeed enormous and the sun, as well as many of the stars, shows in abundance one of the most characteristic elements of radioactive transformations—helium. The mechanism of the radiation, it is true, remains unknown. But the necessity of such an explanation will perhaps not be so imperious in the near future. The problem tends to assume a new aspect of the highest philosophical import. The physicists of the new school are disposed to admit and appear to have proved a fundamental identity [1] between the mass of a body and its internal energy. If matter is no more than energy, we may foresee what a beautiful simplicity physics may sometime assume. On this basis the sun would possess a total energy (easy to calculate since we know its mass) of 2×10^{54} ergs, assuring to it a duration in the future of several hundred billion centuries with the present loss of energy by radiation. It would then without doubt die of good old age unless destroyed by direct collision with some other star.[1] But let us not trouble ourselves about this and come back to our subject.

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[1] Of course on the condition of the suitable choice of units.

INTERIOR EQUILIBRIUM OF THE SUN.

A mass of gas subject only to the mutual gravitation of its parts, such as is the sun, tends to assume a spherical shape. The resultant of the attracting forces at each point is then directed toward the center. However, there are two particular ways in which this equilibrium may become established. In an immobile fluid the temperature can be equalized only through conductivity, and if that is high, the temperature will everywhere be finally the same. This is an isothermal equilibrium. If, on the other hand, the fluid mass is subject to convection currents and the conductivity is negligible, the temperature will differ at different places and depend upon the local pressure.[2] This is an adiabatic equilibrium.

Now, the sun is gaseous and gases are generally very poor conductors for heat. Moreover, the loss of heat by radiation is relatively very small. Further, the sun seems subject to incessant movements of which the spots and faculæ are evidence. Therefore, it must be in adiabatic equilibrium. Postulating this, we may study mathematically the distribution of pressures and temperatures in the interior of a star formed thus of a perfect gas when we know its total mass, its mean density and peripheral pressure (supposed to be zero). With these data known, the problem admits of solution and the pressures and temperatures will be found to increase very rapidly toward the center. For instance, for a sun composed of hydrogen, assumed monatomic at high temperatures, the density at the center will be about 8, the pressure 8 billion atmospheres, and the temperature 24 million degrees. Similar calculations give for other gases results of the same order of magnitude. This is all we may hope to obtain.

One point to be noted is that all this assumes an apparent contour to the sun, which takes away from Schmidt's theory one of its most seducing advantages. But there is something better: The sun radiates toward us and yet the quotient of the heat lost by the lowering of the temperature may in certain cases be negative; that is, the more heat the sun sends to us the warmer it may get. This is called the "paradox of Lane" and it is a good one. However, we have here a complex effect very analogous to the accelerating action of a resisting medium upon the velocity of a planet or comet,[1] an effect often cited in the case of Encke's comet.

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[1] Such as was considered by M. P. Salet in his article in the Revue du Mois (1911), "Le soleil doit-il s'éteindre?" (Will the sun become extinguished?).

[2] A gas compressed in a receiver impermeable to heat becomes heated, when expanded, cooled.

The theory of Lane takes no account of the rotation of the sun which is 25 times slower than that of the earth. M. Emden, taking his suggestion from Helmholtz, has filled this gap and shown that, the given conditions remaining the same, the gaseous mass would separate into discontinuous layers slipping continuously upon each other and having the form of hyperboloids of one sheet.[2] (Fig. 4.) In the middle latitudes the slipping would be the greatest. This slipping produces through friction deep-seated eddies which could be the initial causes of sun spots and give a remarkable explanation of the zones in which they appear. Indeed, this seems to be the best explanation of the whole phenomenon.

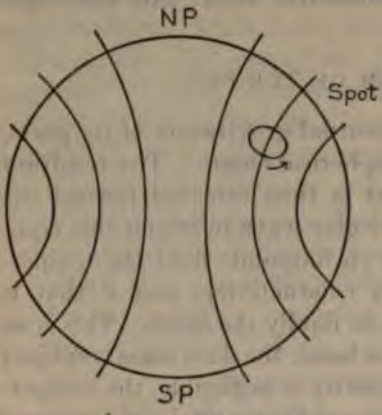

FIG. 4.

ELECTRIC AND MAGNETIC PHENOMENA.

We have so far treated only of the mechanical and optical phenomena of the sun. But we have every reason to suppose that the sun exhibits electric phenomena. All hot bodies do. Metals in particular (but not they alone) at high temperatures emit negatively charged particles (electrons) in great abundance. Richardson and Harker, at temperatures of about 1,500° obtained currents of 1 ampere per square centimeter of heated surface. The law connecting the current with the temperature is exponential. The emission from the sun must therefore be considerable. Further, the spectrum of the chromosphere includes a great number of lines which can be reproduced in the laboratory only by electrical processes. Finally, the sun spots have an undoubted although indirect influence upon terrestrial magnetism which is shown by the general concordance between the magnetic variations and the frequency of sun spots.[3] We are thus almost inevitably led to conclude that the sun is magnetized, an hypothesis incompatible with its high temperature, or, and this is infinitely more probable, that it is the seat of huge convection currents of charged matter.

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[1] It would seem at first sight as if a resistance ought to diminish the velocity. And so it would in an indeformable orbit as a consequence of the decrease of total energy. However, here the orbit is not invariable and the interdependence of the elements alters the case in every way.

[2] The aspect of the corona especially toward the poles sometimes resembles these.

[3] We know that the latter vary periodically each eleven years.

It seems extremely probable therefore that the solar matter is electrified. The radiation pressure which, as Maxwell demonstrated and experiment confirmed, is exercised upon any body struck by light, helps in the expulsion of the charged particles. The wings and filaments of the corona are doubtless due to this force which also explains the tails of comets. They are probably real cathode rays which the least magnetic field will deviate (M. Deslandres) and which volute around the lines of force. The corona thus gives us an image of the general magnetic field of the sun analogous to the terrestrial magnetic field (a sphere uniformly magnetized) and also similar to that of a rotating sphere electrically charged (pl. 1, figs. 1, 2). Along another line of reasoning, the interpretation of the prominences has shared in these new notions. It has been thought strange that a gas should have velocities of upwards of a hundred kilometers a second. But in an ionized gas only an infinitesimal number of the molecules participate in sending out the light (Perot). These few may alone have the enormous velocities within a gas itself almost immobile, just as is the case of the canal rays of a Crookes' tube.

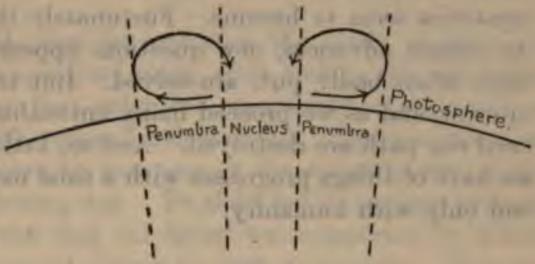

FIG. 5.

A brilliant discovery in America in 1908 throws further light on all these theories. Hale, by means of the Zeeman phenomenon, has shown, within the nuclei of sun spots, magnetic fields of 3,000 or 4,000 Gausses, roughly normal to the surface and explaining perfectly the enlargements and doublings of the corresponding lines in the spectrum. Indeed, these magnetic fields seem to be vortices of electrified matter: the ionization would have to be no more intense than that observed in the laboratory either in vacuum tubes or in the neighborhood of hot bodies.

Connected with this same line of thought is the study of the radial velocities in the various chromospheric layers. This has permitted Deslandres, Evershed, and St. John to investigate the phenomena occurring in sun spots. Above the penumbra, the absorbing vapors spread out from the center of the spot parallel to the surface; arriving at the peripheral facula, they rise, come back higher toward the center (fig. 5) and are finally engulfed within the cavity (nucleus) of the spot where other researches have shown relatively low temperatures. As in the case of eddies in rivers, the cause of this suction may be looked for in the subjacent whirlpools, the very ones which probably develop the magnetic fields and which the theory of Emden so nicely predicts.

Very recently these researches have been extended and it is thought that the evidence shows that there is about the sun a magnetic field analogous to that about the earth. We have just spoken of this in connection with the corona, but it should be further manifested both in the Zeeman phenomena and the helicoidal movements in the prominences. These experiments are not at present fully completed and their discussion is in progress. We just call your attention to them.

In the case of the sun, where so to speak, all the resources of modern physics have been given rendezvous, we find ourselves very far from the huge ball of fire which our fathers naïvely believed they saw. There is no doubt that we have to do with one of the most powerful creative organs of nature and the more we advance the greater the mysteries seem to become. Fortunately this is only apparently so. As science advances, new questions appear before indeed the older ones, often badly put, are solved. But the latter often lose their interest, and as we proceed many untenable hypotheses which darkened our path are destroyed. And so, little by little, the knowledge we have of things progresses with a tidal motion which will doubtless end only with humanity.

THE FORM AND CONSTITUTION OF THE EARTH.[1]

By Louis B. Stewart, D. T. S.

The beginnings of astronomy probably date from the earliest development of the human intellect; and that it should be the oldest of the sciences need not be a matter for surprise when we consider the striking and interesting nature of its phenomena and the numerous services which it renders to mankind. Among the many questions requiring answers that would present themselves to a thoughtful observer possibly one of the first was that of the form and magnitude of our earth.

To a spectator placed upon an eminence the earth, as far as it could be seen, appeared as a level plain, after making due allowance for minor inequalities, so that primitive man regarded the earth as flat, surrounded by an otherwise shoreless ocean. The sun at setting plunged beneath this ocean to reappear at the opposite side of the horizon at rising the following day. To allow for his passage beneath the earth it was conceived that the latter was supported by pillars between which the sun passed during his nightly journey. Thus the Greeks explained the motion of the sun, and they claimed that they were indebted to the Egyptians for their astronomical knowledge.

The teaching of the Hindoos was even more fanciful than that of the Greeks. They taught that the earth is in the form of a hemisphere, resting with its flat surface on the backs of four elephants which in their turn stood upon the back of a gigantic tortoise. The question: What supports the tortoise? received the answer: The endless ocean. The too curious inquirer who wished to know what supports the ocean, was met with the reply that it extends all the way to the bottom. As there is no statement that has come down to us concerning the nature of the bottom or to what it is indebted for its support, we must infer that the last answer stilled all further inquiry.

Leaving these fanciful theories, we find that in comparatively early times more correct views as to the form of the earth were held by some philosophers, based no doubt upon the reports of phenomena observed by mariners and travelers, who found that the highest promontories disappeared from view as they drew away from the land; that a ship gradually vanished below the horizon in a manner that precluded the idea of a flat earth; that the sea horizon always appears circular. These and other phenomena, such as the varying meridian altitudes of stars as one travels in a north or south direction, must have given rise to a belief in the curvature of the earth in the minds of early astronomers. Thales, and after him Aristotle, is said to have taught the sphericity of the earth, and it is not surprising that we soon find attempts being made to determine its dimensions.

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[1] Retiring president's address, annual meeting, Jan. 13, 1914. Reprinted by permission from the Journal of the Royal Astronomical Society of Canada, January-February, 1914.

To Eratosthenes is due the honor of being the first of whom we have any record to make an estimate of the circumference of the earth based upon measurement. He was born at Syene, in southern Egypt, in the year 276 B. C., and, his ability being early recognized by Ptolemy Euergetes, he was placed by him in charge of the Alexandrine library. His geodetic measures consisted in noting that at Syene, at the time of the summer solstice, the sun passed through the zenith of the place, as was shown by a vertical object casting no shadow; while at the same time at Alexandria such an object cast a shadow of such a length as to show that the sun's rays made an angle with the vertical equal to one-fiftieth of a whole circumference. He concluded, then, that as the two places were nearly on the same meridian the distance between them is one-fiftieth of the whole circumference of the earth. The distance being estimated at 5,000 stadia, the circumference of the earth becomes 250,000 stadia. As we do not know the precise length of his stadium, we are unable to estimate the accuracy of this determination. We now know that the longitudes of the two places differed by 3°; also the amplitude of his arc was too small by 15′. Notwithstanding these sources of inaccuracy, however, great credit is due to him for inaugurating a correct method for determining the dimensions of the earth.

Cleomedes, to whom we are indebted for the account of Eratosthenes's operations, suggested that if two gnomons be set up at two places on the same meridian the lengths of their shadows on the same day would serve to determine the amplitude of the arc joining the places. His suggestion thus contained the germ of the method used at the present day to measure the length of a meridian arc.

According to the same writer, another determination of the earth's circumference was made by Posidonius about a century and a half later. This observer noticed that at Rhodes the bright star Canopus just appeared in the horizon when at meridian passage, while at Alexandria it had an altitude equal to one forty-eighth of a circumference. As the distance between the two places was estimated to be 5,000 stadia, the whole circumference becomes 240,000 stadia.

From this time interest in the sciences in Egypt and Greece appears to have languished, and during the Dark Ages the only country in which astronomical science was cultivated appears to have been Arabia. In the year 814 an Arabian caliph proposed to his astronomers the problem of measuring an arc of the meridian. From a selected spot on the plain of Singar, near the Arabian Gulf, one party was dispatched northward and another southward, each with instructions to measure as they went and continue their work until the altitude of the pole was observed to have changed by 1°. The northern party found 56 miles and the southern party 56⅔ miles as the length of 1°. The English equivalent of the latter value, which was accepted as being the most accurate, is about 71 miles.

It was not until the sixteenth century that Europe, having awakened from the lethargy of the Dark Ages to new intellectual life, entered upon the era of development of which we have not yet seen the end. Among the various activities in which this newly found energy sought an outlet may be noted the exploration of foreign lands. America had been discovered, and in 1521 Magellan had completed the circumnavigation of the globe; and it may have been this latter achievement that turned men's attention to the problem of determining the earth's dimensions.

In 1525 Jean Fernel, court physician to Henry II of France, and a cultivator of the mathematical sciences, measured the length of a meridian arc near Paris. His method was so crude as to be but a slight advance upon those of the ancient astronomers which have already been considered. He measured the length of his arc by counting the revolutions of a carriage wheel while driving from one end of it to the other; and his astronomical observations were made with a triangle used as a quadrant. He found the length of 1° to be 365,088 feet, a result very near the truth.

It is not proposed to give an exhaustive account of all the geodetic surveys of the last three centuries, but only to notice briefly those that embodied some improvement in method or were important in their results.

A great advance upon previous methods was now for the first time made by Snellius, who employed the method of triangulation to measure the length of a meridian arc, the method which has been in use ever since, and is superior to all others on account of its accuracy and cheapness, combined with adaptability to any country, whatever its nature. He measured a base with a chain between Leyden and Soeterwood, and his chain of triangles, 33 in number, extended from Alcmaar to Bergen-op-Zoom. This distance, projected upon a meridian, gave a meridian arc having an amplitude of 1° 11′ 05″, which made the length of 1° to be 55,074 toises, a toise being equal to 6.3946 English feet. His angles were measured with a graduated semicircle 3½ feet in diameter, and his latitudes observed with a quadrant 5½ feet in diameter, neither of these instruments being provided with a vernier or telescope sight, as neither had been invented at that time. It was not to be expected under those circumstances that his result would be remarkable for precision, in spite of the precautions which he took to secure it; in fact, his length of a degree is in error by about 2,000 toises. Though his triangles were solved as plane triangles, neglecting spherical excess, the labor involved in their solution will be realized when we remember that at that time logarithms had not been invented.

The first attempt at degree measurement in England was made by Norwood about 1635. He measured with a chain the distance from London to York, occasionally, however, resorting to pacing, and determined his latitudes by observing altitudes of the sun on the same day, June 11, in the years 1633 and 1635. His adoption of Fernel's method instead of following in the path marked out by Snellius, is to be regarded as a retrograde step, in spite of the fact that his value of a degree, 367,176 feet, or 57,420 toises, is so near the truth. Its accuracy, however, must have been the result of a compensation of errors.

Another improvement was now introduced by Picard, who used, in 1669, telescope sights on his angle-measuring instrument. He measured a base line with wooden rods of 5,663 toises, and a base of verification of length 3,902 toises, and his triangulation extended from Malvoisine, near Paris, to Sourdon, near Amiens. His result for the length of 1° was 57,060 toises.

Picard's work was rendered famous in another way, in that it furnished Newton with data by which he was enabled to establish the law of universal gravitation. About 1665, when he had retired from Cambridge to his home at Woolsthorpe on account of the great plague, his thoughts were first turned to the subject of gravity. Reasoning from Kepler's laws he readily proved that the planets are kept in their orbits by an attractive force directed to the sun whose intensity varies inversely as the square of the distance. It at once occurred to him that if this law is universal it must be in virtue of it that the moon is retained in her orbit about the earth; that the distance through which the moon falls toward the earth, or is deflected from a tangent to her orbit, in a unit of time stands in a simple relation to that through which a body falls in the same time near the earth's surface.

To be more explicit, the distance through which a body falls in a given time varies directly as the attractive force and the square of the time. The moon's distance is 60 radii of the earth; therefore the force of the earth's attraction acting upon it is only 1/3,600 of its value at the earth's surface, so that the moon falls in one second only 1/3,600 as far as a body at the earth's surface. In one minute, or 60 seconds, it will fall 3,600 times as far as in one second; therefore the moon should fall as far in one minute as a body near the earth's surface falls in one second, or 16 feet.

Newton, however, by assuming 60 miles to a degree, the value used by navigators at that time, found only 14 feet for that quantity.

He considered, therefore, the discrepancy a proof of the inaccuracy of the law of the inverse square, and laid aside for the time his investigations in that direction. In January, 1672, at a meeting of the Royal Society, the result of Picard's work was mentioned, giving 69.1 miles as the length of a degree, and Newton was able to revise his calculations, with the result that his hypothesis was amply verified. This is generally supposed to have led to the publication of the Principia, which laid the foundation of gravitational astronomy, though some affirm that Newton delayed the publication of his great work until he had proved that a spherical body attracts an outside body as if all of its matter were concentrated at its center.

Up to this time the size of the earth had been investigated on the supposition that its form is spherical, and that it is therefore only necessary to measure the length of a degree on its surface in order to determine its dimensions. A discovery was made, however, by Richer (1672) which turned the attention of astronomers to the possibility that its form may deviate materially from that of a sphere. He had been sent by the Academy of Sciences of Paris to the Island of Cayenne to make certain astronomical determinations, and while there he found that his clock, which had been regulated in Paris to keep correct time, lost about two and one-half minutes daily, so that it was necessary to shorten the pendulum by one and one-fourth lines to make it beat seconds. His report was received with doubt until confirmed by the subsequent observations of Halley, Varin, and Deshayes on the coasts of Africa and America. The phenomenon was first explained by Newton in the third book of the Principia, where he showed that it is the result of a decrease in the force of gravity in the neighborhood of the equator due to increased distance from the center of the earth combined with the effect of centrifugal force. He also investigated the figure of the earth and showed that it must be an oblate spheroid. As a consequence of this the lengths of the degrees of latitude must increase with the latitude.

Between the years 1684 and 1718, Picard's triangulation was extended by J. and D. Cassini southward as far as Colidoure and northward to Dunkirk, making a total amplitude of 8° 31′. The northern portion of the arc, having an amplitude of 2° 12′, gave 56,960 toises as the length of a degree, while the southern portion gave 57,097 toises. These results seemed to negative the theoretical conclusions reached by Newton in the Principia, and to point to the prolate spheroid as representing the true form of the earth. A heated controversy arose in consequence, and in the excitement thus occasioned, as well as from a desire to know the truth of the matter, the Academy of Sciences resolved to apply a crucial test of the rival theories by measuring a meridian arc at the equator and another at the Arctic Circle.

Two parties were accordingly organized; one composed of Maupertuis, Clairaut, Camus, Le Monnier, the Abbé Outhier, and Celsius, being commissioned to measure an arc in Lapland; and the other, composed of Godin, Bouguer, and de la Condamine, a meridian arc in Peru.

The polar party landed at the town of Tornea at the mouth of the river of the same name in the beginning of July, 1736. They began by exploring the river, and finding that the course of its valley is nearly north and south and flanked on either side by high mountains, they resolved to establish the stations of their triangulation on these mountains. The tops had to be cleared of timber, and the signals were constructed in the form of cones composed of several large trees denuded of their bark, their white surfaces being thus visible at a distance of 10 or 12 leagues. The angles were measured with a quadrant having a radius of 2 feet, whose accuracy they verified by measuring all the angles at a station that close the horizon. The three angles of each triangle were also measured, and also check angles, which were sums or differences of necessary angles at a station.

The measurement of the angles occupied 63 days, and on September 9 the party reached Kittis, the most northerly station, and made preparations for their astronomical work. Two small observatories were built, one of which contained a small transit instrument and a clock, the former instrument being set up exactly over the center of the station. The transit instrument was used in determining time and the azimuths of the two stations visible from the observing station. The other observatory contained a zenith sector having a telescope 9 feet in length which was used in determining the difference of the latitude of the two terminal stations. Observations of δ Draconis, which passed near the zenith of the place, were taken between October 4 and 10. The party then proceeded to Tornea and commenced observations on the same star on November 1, finishing on the 5th. Their instrument gave the difference of zenith distance of the star as observed at the two stations; this difference, corrected for aberration, precession, and nutation, gave the amplitude of the arc $57' 26.93''$.

The final operation was now the measurement of the base line. This had been intentionally postponed until winter, as its site had been so chosen that the greater part of its length lay along the River Tornea, its extremities only being on land. The frozen river would thus afford a level surface upon which to carry on their measurement The party had brought with them from Paris a standard toise, called afterwards the "Toise of the North," which, with another taken by the Peruvian party, had been carefully adjusted to be at standard length at 14° Reaumer. By careful comparison with this standard they prepared eight wooden rods each five toises in length and terminating in metal studs, which were used in measuring the base.

This work was begun on December 21, the party having been divided into two, each taking four rods and working independently, the rods probably being laid upon the snow with their ends in contact. The difference between the measurements was only 4 inches in a length of 7,406.86 toises.

It only remained now to compute the length of the meridian arc contained between the parallels of the two terminal stations. This was found to be 55,023.5 toises.

Seeing that the resulting length of a degree would be far in excess of that in the latitude of Paris, they submitted their work to a rigid examination. An investigation of the division errors of the arc of their sector was made, and the amplitude of their arc redetermined increasing it to 57′ 30.42″. Observations for azimuth were made at Tornea, and it was found that the resulting azimuth differed by 34″ from the value computed through the triangulation from the observations at Kittis; but this would have but a trifling effect upon the length of the meridian arc.

Their final value for the length of a degree was 57,437.9 toises.

Meanwhile the Peruvian party had selected as the scene of their operations the valley in which Quito is situated, and which lies between the double range of mountains into which the Andes are there divided. By placing the stations of their triangulation alternately on opposite sides of the valley, they were able to form extremely well-conditioned triangles, though the labor involved in occupying the stations may be inferred from the fact that seven of them were situated at heights exceeding 14,000 feet. A base line was measured near each extremity of their chain of triangles, the northern base being near Quito, and having a length of 7.6 miles, and the southern base a length of 6.4 miles. In their astronomical work they observed the absolute zenith distances of stars, thus finding the latitudes of their terminal stations, and not merely their difference of latitude. The same stars, however, were observed at the two stations, so that their difference of latitude was unaffected by errors in the star places.

The amplitude of their arc was 3° 07′ 01″, and its length 176,945 toises, thus giving 56,753 toises as the length of 1° at the Equator, which was about 685 toises shorter than the value found in Lapland, the length of a degree in France being intermediate between these.

Thus was it demonstrated finally that the form of the earth is that of an oblate spheroid, and subsequent arc measurements have only served to confirm this conclusion.

The problem that now presented itself was the determination with all possible precision of the exact dimensions of the terrestrial spheroid. Geodetic surveys were soon in progress in every civilized country.

On representations from Count Cassini de Thuri to the Royal Society of London of the advantages that would be derived from the extension of the French triangle chain into England, the British Ordnance Survey was begun in 1784, and by 1851 the whole of the British Isles was covered with a network of triangles. This triangulation, however, as in the cases of all modern surveys, was designed to serve the double purpose of arc measurement and also as the basis of an accurate topographic survey.

The year 1791 saw the inception of the grandest project ever devised for the establishment of a standard of length. Certain prominent members of the Academy of Sciences, among whom were Laplace and Lagrange, proposed to the Constituent Assembly of France—and received their sanction—that the ten-millionth part of the earth's meridian quadrant be adopted as the national standard of length, to be called the meter. It was further proposed that this length be determined by the measurement of a meridian arc extending from Dunkirk to Barcelona, and comprising 9° 40′ of latitude. This was accordingly carried out, the work being intrusted to Legendre and Mechain, and the length of the arc was found to be 551,584.7 toises, and its amplitude 9° 40′ 25″.

The commission appointed to revise their calculations and to determine the length of the meridian quadrant combined this new French arc with the Peruvian arc, and thus found for the length of the meridian quadrant 5,130,766 toises, which gave as the length of the meter 0.5130766 in parts of the toise of Peru.

It would be impossible even to notice briefly all the arc measurements that were now made in different countries, each contributing its quota to the growing mass of data for determining the earth's figure. It is sufficient to state that in 1799 Laplace made a determination of the elements of the spheroid based upon a discussion of nine meridian arcs measured in Lapland, Holland, France, Austria, Italy, Pennsylvania, Peru, and at the Cape of Good Hope. In this discussion Laplace made use of the expression

$$d = \mathrm{A} + \mathrm{B}\sin^2\varphi$$

which gives the length of a degree of the meridian in a given latitude, A and B being functions of the semiaxes. As only two such equations are necessary in order to determine the two unknowns, some principle had to be assumed in order to obtain the best values from all the measurements. Laplace adopted the principle that the unknowns should be determined so as to fulfill the conditions that when substituted in the observation equations they should make the algebraic sum of the errors in d equal to zero, and their sum, when all are taken positively, a minimum. This gave the expression

$$d = 56{,}753 + 613.1\sin^2\varphi$$

for finding the length of a degree in any given latitude. On applying this expression to the Lapland arc, however, it was found to give a value 138 toises shorter than that found by observation, from which Laplace concluded that the earth deviates considerably from the spheroidal form. It must be mentioned, on the other hand, that in 1801 an expedition was sent from Stockholm in charge of Svanberg with instructions to measure the Lapland arc, with the result that he found for the length of 1° a value about 200 toises less than that found by Maupertuis, thus conforming more closely to the value given by Laplace's empirical formula.

During the nineteenth century geodetic work was carried on vigorously by every civilized nation, and great improvements were introduced in instruments and methods. The result of this activity is that we now have the following arcs available for investigating the earth's figure: The British-French arc, extending from the Shetland Isles through France into Africa, and covering 27° 01′ of latitude; the Russian arc, extending from the Danube to the North Sea and having an amplitude of 25° 20′; the arc of the parallel in latitude 52°, extending from the west coast of Ireland to the Ural Mountains and embracing 68° 55′ of longitude; the arc lately measured in Spitzbergen between latitudes 76° 38′ and 80° 50′ N., which is important on account of its high northern latitude; the Indian arcs, including 24 meridian arcs and 7 arcs of parallels of latitude; the South African arc; the Peruvian arc, lately remeasured; the American oblique arc following the Atlantic coast for a distance of 1,623 miles; the western oblique arc, extending along the Pacific coast; the arc of the parallel of latitude 39° N., extending from the Atlantic to the Pacific; the ninety-eighth meridian arc, now well under way and to which Canada and Mexico have been invited to contribute their shares and which when complete will extend over 50° of latitude.

A proposal made by Sir David Gill should be here mentioned. When director of the Royal Observatory at Cape Town he instituted the project of extending the South African triangulation through Natal and then on through the whole extent of the African Continent, following the meridian of 30° of east longitude, to Cairo, and thence on to connect with the Russian arc on the Black Sea. This arc will have a total amplitude of 105°.

The application of the electric telegraph to longitude determination has given measurements of arcs of parallels of latitude an importance in these investigations fully equal to that of meridian arc measurements.

As additional data became available investigations were made from time to time to determine the spheroid that would best represent the measured arcs. The most important of these were those made by Bessel in 1841; Col. A. R. Clarke, of the British Ordnance Survey, in

1866, and another in 1880; and Helmert in 1887. Clarke in 1866 also investigated the dimensions of the earth regarded as an ellipsoid having three unequal axes, using the same data as in determining the spheroid, and, as was to be expected, it satisfied the observations better than the spheroid. The compression of the Equator—which on this assumption is an ellipse of small eccentricity—was thus found to be 1/3,281, and the longitude of one extremity of its major axis 15° 31′ E. Another similar investigation made by Clarke in 1878 reduced the compression of the Equator to 1/13,706 and made the longitude of an extremity of its major axis 8° 15′ W. The fact that the use of additional data diminished the eccentricity of the Equator is perhaps significant, showing that, disregarding local irregularities, the earth probably departs but little from the spheroidal form.

It must not be inferred, however, that any spheroid or ellipsoid could ever be found that will exactly represent all observations. There will always be differences between the computed or geodetic positions of points and those found by astronomical observation greatly in excess of the errors of observation. These differences arise from deviations in the direction of the plumb line, due to local irregularities of density of the matter composing the earth's crust.

An important improvement in the method of investigating the form of the earth was recently made by J. F. Hayford, of the United States Geodetic Survey, using the data of that survey alone. He made use of 507 astronomical observations of latitude, longitude, and azimuth, connected with their triangulations, and allowed for the attraction of the earth's crust on the assumption that the condition termed "isostasy" exists at a depth of 114 kilometers. Three different assumptions of depth were made, but this gave the best results. His values were:

$$a = 6{,}378{,}283 \text{ meters}, \quad c = 1:297.8$$

The following is a tabular statement of some of the determinations of the elements of the terrestrial spheroid made during the nineteenth century and to date:

Years.	By whom.	c.	Length of meridian quadrant.	Years.	By whom.	c.	Length of meridian quadrant.
1806	Delambre	1:334	10,000,000	1866	Clarke	1:295	10,001,887
1819	Walbeck	1:302.8	10,000,268	1868	Fischer	1:288.5	10,001,714
1830	Schmidt	1:297.5	10,000,075	1872	Listing	1:289	10,000,218
1831	Airy	1:299.3	10,000,976	1878	Jordan	1:286.5	10,000,681
1841	Bessel	1:299.2	10,000,856	1880	Clarke	1:293.5	10,001,869
1856	Clarke	1:298.1	10,001,515	1887	Helmert	1:299.15	10,002,041
1863	Pratt	1:295.3	10,001,924	1906	Hayford	1:297.8	....

In addition to the method of determining the earth's figure by geodetic measurements there are others that must be considered briefly. Foremost among these is the method by pendulum experiments. In 1743 Clairaut published his work on the figure of the earth, which contains a remarkable theorem showing a connection between the force of gravity at a point on the earth's surface in given latitude and the compression of the earth. The part played by the pendulum in the application of this method is the determination of the force of gravity, as the time of oscillation of a pendulum varies directly as the square root of its length, and inversely as the square root of the force of the earth's attraction. If then the time of vibration of a pendulum of a known length be observed, the value of the force of gravity follows.

Since 1808 pendulum experiments have been made in various parts of the world ranging from the Southern Hemisphere to Greenland and Spitzbergen. In 1901, by a discussion of about 1,400 observations of g made during the nineteenth century, Helmert obtained the value of the compression 1:298.3.

Other methods of finding this quantity, which are purely astronomical, are by lunar perturbations and lunar parallax. There are certain disturbances of the moon's motion that are caused by the earth's spheroidal figure, and their expressions are therefore in terms of the compression. If then the amount of the lunar perturbations is found by observation the compression of the earth can be found from it. The value found in this way is 1:297.8.

Observations of lunar parallax may also be employed for this purpose, whether made by the meridian method or the diurnal method. Sir David Gill has lately advocated the use of this latter method. He considered that if all the observatories situated not too far from the Equator were to cooperate in taking systematic observations of the moon a very precise value of the compression could be found.

To sum up: It is probable that the final values of the major semiaxis and the compression of the elliptic meridian will be found to differ but little from the quantities:

$$a=6,378,200$$
$$c=1:298$$

To return to the term "isostasy"—this condition may be defined as follows: Imagine a spheroid concentric with the terrestrial spheroid and whose surface is everywhere about 76 miles within that of the latter, then the pressure on all parts of the surface of this inner spheroid, due to the weight of the superincumbent crust, is the same. In other words, all prismatic columns of the earth's crust having the same cross section and extending from the surface down to the isostatic surface—as it may be termed—have the same mass. Hayford's investigations show that geodesy furnishes positive proof of the existence of isostasy, and places the isostatic surface at a depth of 76 miles, and shows, moreover, that that depth is almost certainly not less than 62 miles, nor greater than 87 miles.

Pendulum experiments also show that there is a deficiency of gravitating matter beneath mountain ranges and table lands, and an excess near the seashore. This has been especially observable in India, where at elevated points near the Himalayas the value of the force of gravity has been found to be the same as it would have been if there were no intervening mountain mass between the point of observation and sea level. On the other hand, in the neighborhood of the Indian Ocean an excess of attracting matter was revealed. Facts like these first led Archdeacon Pratt to suspect the existence of isostasy.

We see, however, various agencies at work on the earth's surface that must tend to disturb this isostatic condition. Mountains are being worn down by the action of water and their materials transported to lower elevations, and there deposited. If, then, this state of isostasy is maintained, it must be effected by a counter flow of material in the opposite direction somewhere below the surface. Geology furnishes evidence that this takes place by the fact that in spite of rapid denudation mountain regions are often observed to maintain their elevation, as if they were raised from below as fast as they are torn down from above. Also sedimentary rocks of great thickness, such as the Paleozoic formations of the Appalachian region, contain shallow-water fossils throughout, showing that the sea bottom must have sunk as fast as sediment was piled upon it. Similar examples occur in many other localities.

On the theory of isostasy the interior portion of our globe, within the layer of compensation is composed of material of the same density at equal distances from the center—or rather, the layers of equal density are concentric spheroids. The theory that the crust of the earth is only a few miles in thickness, and rests upon an intensely heated molten interior, is no longer tenable. It is now known that the earth as a whole possesses a high degree of effective rigidity, as great as if it were composed throughout of steel. It is no doubt true that the interior of the earth is in an intensely heated condition and that it appears to possess some of the properties of a fluid; at the same time it behaves in many respects as a solid.

A heated and therefore cooling body like the earth must shrink; and thus its solid outer crust would be continually under the necessity of adapting itself to a contracting interior. This would give rise to enormous tangential stresses in the crust to which it must eventually yield. That this has taken place in the past is evidenced by the plications and dislocations shown in the rock strata that compose the crust; and to the fact that it is still taking place are probably due the earthquake shocks that are of almost daily occurrence in some part of the world. It is practically certain that no earthquake center has been situated at a greater depth than 30 miles below the earth's surface, and probably not below 20 miles, from which it would appear that any transfer of material that may occur at greater depths must take place without shock, and that consequently the material there must behave as a fluid.

The most valuable evidence regarding the earth's interior is afforded by the study of earthquake phenomena. An earthquake shock occurs in some part of the world, and at once elastic vibrations are set up in the surrounding material which are propagated in all directions from the center of disturbance, and leave their records upon the seismographs installed at stations in various parts of the world. By a study of these records some important conclusions can be drawn.

In the first place it is found that the earthquake waves that reach stations within about 20° of the center of disturbance are of an entirely different character from those observed at more distant stations. The former are confined to the earth's crust, while the latter travel through the earth by the shortest route, or possibly by brachystochronic routes, or routes of shortest time. It is with the latter that we are chiefly concerned.

A study of a great mass of data regarding these long distance waves has revealed the following facts:

These waves may be divided into preliminary tremors—of which there are two phases—and large waves. The time required for the waves of the first phase to travel from an earthquake center to a distant station is proportional to the length of the chord drawn between those points. From this it may be inferred that these waves travel at a uniform rate along chords, that rate being about 9.25 kilometers per second. The times required for waves of the second phase to reach the distant stations are not proportional to the lengths of the chords, but show a velocity increasing with the distance traveled according to some law not yet understood. The large waves are propagated along the surface of the earth, and have a uniform velocity of about 2.95 kilometers per second.

The generally accepted view regarding the preliminary tremors is that those of the first phase are longitudinal waves, while those of the second phase are transverse or distortional waves. As the velocity of propagation of a longitudinal wave varies as the square root of the ratio of the volume-elasticity to the density of the medium, it appears that, whatever the composition of the interior of the earth, the ratio of volume-elasticity to density must be constant at all depths, and therefore constant with varying density of the medium traversed. This is a property of gases. If the waves of the second phase are transverse waves it would appear that this same medium is capable of transmitting such waves, which can not be transmitted by fluids or gases. Until the law of their increase of velocity with distance, and therefore with depth, is better understood, it is too soon to draw any conclusions regarding the nature of these waves, and of the medium by which they are transmitted.

Prof. Nagaoka, of the University of Tokio, investigated the densities, elasticities, moduli of rigidity, and the velocities of transmission of longitudinal and transverse waves, for the various kinds of rock that compose the earth's crust. An important result is to show that while there is a slight increase of density in going from the Quaternary to the Archæan rocks there is a large increase of elasticity, so that the rate of propagation of wave motion in the latter rocks is much greater than in the former, the velocities for longitudinal waves going as high as 6 and 7 kilometers per second. It may be stated here that the velocity in an unlimited medium of steel would be 6.2 kilometers per second. It might then be inferred that at great depths in the earth the ratio of elasticity to density may continue to increase with depth to a certain point, so as to permit of the great velocities of wave transmission observable in earthquake phenomena.

Prof. Milne concludes from the velocities of seismic waves at different depths that the materials and general characters of the crust of the earth that are found at the surface may extend to a depth of about 30 miles, but beyond that the material seems rapidly to merge into a fairly homogeneous nucleus. This state probably extends to a depth of six-tenths of the radius, but the remaining four-tenths forms a core which differs in its physical, and possibly its chemical, constitution, from the outer portion. What the state of this nucleus is must be a matter largely of conjecture until we have a fuller knowledge of the state of matter when subjected to the vast pressures that must exist within the earth's interior.

Additional evidence that the earth as a whole is at least as rigid as steel is furnished by a study of tidal phenomena, and also by the variation of latitude. That bodily tides are caused by the moon in the solid earth has been proved by Hecker; and Sir George Darwin found by a study of the tides of long period at different ports, extending over an interval of 33 years, that the ocean tides are about two-thirds as great as if the earth were unyielding. He also showed that this is the ratio that theoretically should exist if the rigidity of the earth were that of steel.

With regard to the variation of latitude, Euler showed that if the earth's axis of rotation and figure do not coincide one axis will revolve about the other in a period of 305 days. All attempts to discover a periodicity in latitude variations, however, were futile until Chandler, by a study of a great mass of material, showed that a period exists, but instead of 305 days he showed a period of 427 days. It was then pointed out by Newcomb that Euler had assumed the earth to be perfectly rigid, and that by assuming its rigidity as equal to that of steel the period would become 457 days. The inference to be drawn from this evidence is that the earth is more rigid than steel.

SOME REMARKS ON LOGARITHMS APROPOS TO THEIR TERCENTENARY.[1]

By M. D'OCAGNE,
Professor at the École Polytechnique.

[With 2 plates.]

The Royal Society of Edinburgh during the last week of July, 1914, fittingly observed the tercentenary of the invention of logarithms by John Napier, Baron of Merchiston, whose name, Latinized in the form of Neperus, has become in French Néper. In July, 1614, Napier published at Edinburgh, under the title "Mirifici Logarithmorum Canonis Descriptio," a quarto work of 56 pages of text and 90 pages of tables, dedicated to the Prince of Wales (later the unfortunate King Charles I), which was to revolutionize the art of numerical calculation, and exercise a prodigious influence on the development of all collateral sciences, astronomy in particular.

We can not on this occasion fail to recall that one of the first and most eager adepts at the new method of calculation was Kepler, who, by his own confession, would perhaps without this aid have given up the preparation of those tables from which with the intuition of a genius he was to evolve the marvelous laws of the planetary movements which bear his name, and which in their turn led Newton to what is undoubtedly the highest human achievement in the realm of natural philosophy—the principle of universal gravitation.

It seems, besides, that Napier, an essentially mystic spirit, must have foreseen all the progress of which his invention was to be the source when he ended the book in which he made that invention known with these words, "Interim hoc brevi opusculo fruamini Deoque opifici summo omniumque bonorum opitulatori laudem summam et gloriam tribuite" (let those who reap the harvest of this small work pay a tribute of glory and thankfulness to God, sovereign author and dispenser of all good).

Logarithms in our day are so familiar to all who have taken up mathematics in any way, even the mere elementary branches, that the extraordinary originality of the discovery which gave them birth is perhaps somewhat shadowed.

On the other hand, those who are unfamiliar with the study of the exact sciences and know logarithms by name only, are apt to see in them a kind of secret conferring on the initiated a mysterious power over numbers.

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[1] Reprinted by permission from La Nature, Paris, July 11, 1914.

The first are at fault in not sufficiently appreciating the great ingenuity of this efficient means of simplifying calculations, the second in attributing to it a character somewhat cabalistic.

For the uses to which they lend themselves there is nothing so simple as logarithms. These uses are founded entirely on a property which we will explain: For every number, the logarithmic tables have another corresponding number which is called the logarithm of the first, and when a number A is equal to the product of two other numbers, B and C, the logarithm of A is equal to the sum of the logarithms of B and C.

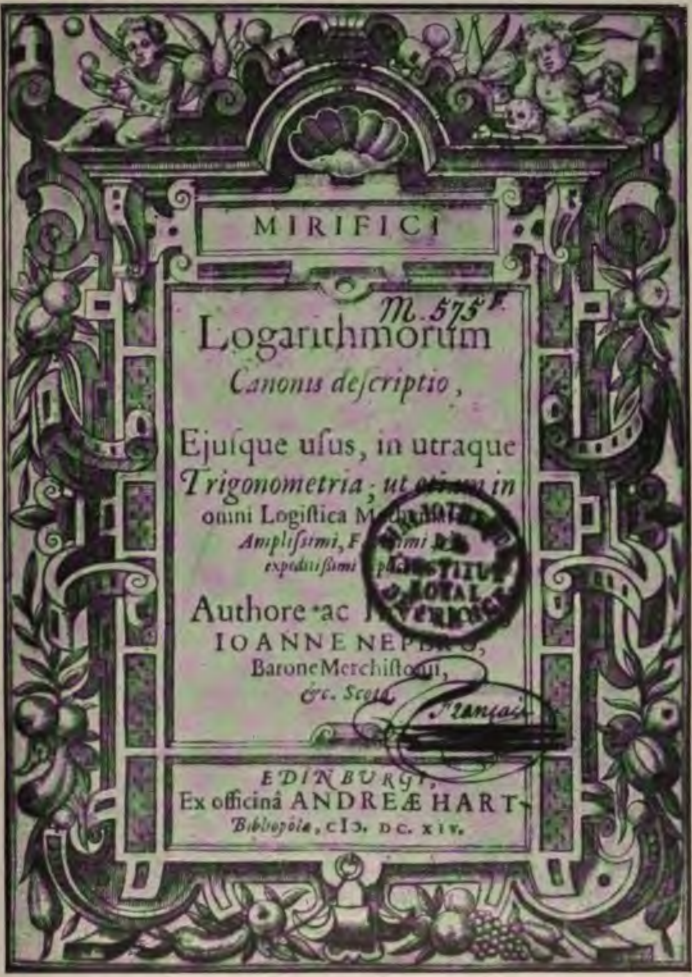
It is this faculty which logarithms confer, of replacing all multiplication by a simple addition, that is the source of all the simplifications attending their use. To obtain the product of B multiplied by C, one looks in the table for the logarithms of B and C (which may be represented by b and c) and performs the addition b plus c. If a is this sum, the table shows the number A of which a is the logarithm; this number A is equal to the product desired, B multiplied by C.

Inversely, if it is desired to divide A by B, the difference, a minus b, of their logarithms is obtained, and if it is found to be c, it is only necessary to read in the table the number C of which the logarithm is c; this number C is the quotient desired.

As a general rule, in order to obtain the product of any number of factors, it is sufficient to take the sum of the logarithms of those factors; this sum is the logarithm of the product which is then read in the table, opposite its logarithm.

In particular, the *nth* power of a number, which is the product of n factors equal to this number, has for a logarithm n times the logarithm of the given number. Inversely, if the *nth* root of a number is desired, it is only necessary to divide by n the logarithm of that number; the quotient obtained is the logarithm of the desired root. Is there need of insisting on the simplicity of this method of working compared with that which made the poor scholars grow pale who were forced to apply the arithmetic rule to the extraction of square and cube roots? It is not uncommon even to find certain students who, deceived by a false appearance, imagine that if they work deeper in the realm of mathematics, they would find need for calculations even more dry and repelling, when, on the contrary, the further one advances, the more are methods discovered which are simple, neat, and apt, designed not only to satisfy but even to delight the mind.

And on this occasion one may be led to ask himself whether, instead of holding young scholars down to the application of processes



MIRIFICI

M. 575 F.

Logarithmorum

Canonis deſcriptio,

Ejuſque uſus, in utraque
Trigonometria; ut etiam in
omni Logiſtica M[illegible]
Ampliſsimi, F[illegible]imi [illegible]
expeditiſsimi [illegible]

Authore ac I[illegible]
IOANNE NEP[illegible],
Barone Merchiſtonii,
&c. Scoto.

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FRONTISPIECE OF THE FIRST EDITION OF NAPIER'S TABLES OF LOGARITHMS.

(Reproduced from the copy in the library of the institute.)

JOHN NAPIER OF MERCHISTON, INVENTOR OF LOGARITHMS.

(After a print in the National Library.)

which in themselves are certainly of great worth though without true practical usefulness, it would not be better to initiate them from the start in the handling of logarithms, reserving the theory for later explanation; this question, unless it be decided a priori, should at least be seriously examined.

The great usefulness of logarithms was everywhere manifest from the start, particularly in trigonometric calculations involving sines, cosines, tangents, cotangents, etc., as in astronomy, especially navigation, so that to the tables of logarithms of numbers there were promptly added those of trigonometric functions.

But it would still be underestimating the exceptional importance of logarithms to consider them only from this utilitarian point of view, however important it may be. In reality, the contribution of this new invention has been found to constitute, not only in the domain of simple calculation, but also in that of pure mathematics considered under the form of algebra, an acquisition of the very first order, the initiator of great progress, both in itself, and because of the unexpected generalities of which it has been the source. There is no need to dwell here on this side of the subject, which to mathematicians is the most captivating, but it is not fitting in this rapid explanation of the whole subject to leave it entirely in the shade.

When a system of logarithms is once formulated there can evidently be deduced from it an infinite number of others by multiplying all the logarithms of the first system by the same factor, whatever it may be. What characterizes each of these systems is the number which takes for a logarithm, unity, a number which is called the base of the system. The simplest system employed for all ordinary uses, and which for this reason is given the name "common," is that of which the base is 10. But strange to say, this is not the system of which Napier at first dreamed; that one had for a base a certain incommensurable number which, like the well-known number π (ratio of the circumference to the diameter), belongs to the class of numbers which mathematicians call transcendant,[1] a number equally designed, however, for universal use by a special notation, and designated by the letter e. Now, and this is somewhat remarkable, it is precisely this initial system of Napier which in the domain of analysis plays a rôle indeed fundamental; it is these Naperian logarithms which enter directly into the speculations of the mathematician, giving them the name of natural logarithms, as it is the common logarithms which constitute the daily implement used by the calculator; the passage from one to the other, moreover, is made easier since it is again a matter of multiplication by a constant factor, the modulus (a multiplication itself effected by means of logarithms).

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[1] These numbers are those which no algebraical equation with integral coefficients can take for a root. Numbers such as $\sqrt{2}$ are indeed incommensurable (as a result expressible only with an infinite number of figures), but they are not transcendant, $\sqrt{2}$ in particular being a root of the equation $x^2-2=0$.

But it is worthy of mention that Napier himself, after having produced his initial system of logarithms which we call Naperian, noted the utility, from a practical point of view, of adopting the common logarithm with the base 10. Death prevented him, however, from realizing this reform, of which he had merely confided the plan to his son, and it is to his friend, Henri Briggs, professor at Gresham College in London, that should be given the credit for making known for the first time in 1624 in his Arithmetica Logarithmica, these new logarithms whose use has become universal.

Except those of the exact powers of 10, as 100, 1,000, etc., the common logarithms of all whole numbers are incommensurable numbers, that is, numbers represented decimally by an infinite succession of figures. In order by their means, to obtain results of calculations closer and closer alike, it is necessary to obtain the logarithms themselves with a greater and greater number of decimals.

It was with 14 decimals that Briggs had the patience himself to calculate the logarithms of whole numbers from 1 to 20,000, and from 90,000 to 100,000. The lacuna of from 20,000 to 90,000 was filled in in 1628 by the Dutch mathematician Vlacq in the second edition of the Arithmetica Logarithmica, published in Gouda. It was in the same year and in the same city that were given by the Englishman Gellibrand, in his Trigonometria Britannica, the first tables of logarithms of trigonometrical functions. It was at this date that logarithms were introduced into the ordinary usage of calculators.

These early tables have constituted a treasure house from which the majority of subsequent editors have borrowed, those who, according to the degree of approximation which they had in view, have merely had to extract from them selected tables more restricted in decimals (falling to 5 and even to 4), in order to introduce improvements in general arrangement, the classification of the numbers, the readability, and finally their accuracy, for it must indeed be admitted that some few errors had crept into the first tables of Vlacq, but these mistakes have had at least the great advantage of establishing the character of those mere copies which otherwise might have been taken for originals. Such was the case with certain tables recovered in China in the course of the nineteenth century, to which the Mandarins, no doubt in good faith, had attributed great antiquity, but the presence therein of mistakes characteristic of Vlacq removed any doubt as to their real origin, and thus prevented Napier from being despoiled of his fame to the profit of some legendary figure rising suddenly from the depths of the history of the Celestial Empire.

It would take much too long to pass in review the editions of tables of logarithms published in various countries during the last three centuries; the number certainly exceeds 500.[1]

As to France, it must not be forgotten that Napier's book, introduced into our country by Henrion, was republished in Lyon in 1620. What are known as "common" logarithms, were brought into France by the Englishman Wingate, who likewise contributed to popularizing the slide rule.

Some tables in seven decimals, by Gardiner, were in 1770, issued in an elaborate edition at Avignon though the work was quite unmanageable on account of its folio form. On the completion of these, Callet reproduced them in 1785, in a volume of convenient size, the execution of which does honor to the capable printer Ambroise Didot. At the time of a new edition of this work, in 1795, Firmin Didot, son of Ambroise, invented the stereotype, which has the great advantage of permitting the correction of mistakes as soon as they are recognized without running the risk of introducing new ones.

No work on logarithms not based on the prototype of Vlacq, was published before the end of the eighteenth century when the adoption in France of the metric system, entailing the centesimal division of the quadrant, required the calculation of new trigonometric tables. The direction of this important work was unfortunately given to Prony who organized it in a truly remarkable way. Having confided the choice of methods and the establishment of formulas to several mathematicians of whom the best known was the illustrious Legendre, and having entrusted the determination of results which may be called primary, to professional calculators, he gave the task of filling the rest of the columns beyond these primary results to assistants who, in the domain of calculation, could be regarded only as ordinary workmen apt merely in performing additions required by the use, directed by the professionals, of the method of differences. It is curious to note that the majority of these assistants had been recruited from among the hair-dressers whom the abandonment of the powdered wig in men's fashion had deprived of a livelihood. It goes without saying that in view of the control of the results (carried out to the fourteenth decimal), all these calculations were done in duplicate in localities distant from one another.

These tables of Prony, called also "du cadastre," of which the publication, cut by Didot to 12 decimals, was interrupted for the time by the failure of the assignats, gave birth, several years ago, to the eight-decimal tables of the geographical service of the Army, executed by the National Printery with type specially cast for the purpose, which made of them a work almost without rival for its beauty.

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[1] Details concerning the most important publications are given in the article, "Numerical calculations" in the French edition of the Encyclopedia of Mathematical Sciences (Gauthier-Villars, 1909), which the author of the present article signed with Prof. R. Mehmkede, Stuttgart.

Finally, it is known that the distinguished professor of astronomy at the Sorbonne, Prof. Andoyer, has now undertaken the task of recalculating a complete table of logarithms, which in this branch of learning, will remain as the most important work of our epoch.

Let us add, as a matter of curiosity, that certain tables, of very restricted length, have been published with a very great number of decimals for the extremely precise calculations exacted by certain purely theoretical questions. We may cite in this connection the Wolfram tables with 48 decimals; those of Sharp with 61 decimals; and finally, those of Adams with 260 decimals. These last contain only the natural logarithms of the numbers 2, 3, 5, 7, 10, and that of the factor (modulus) which permits passing from these logarithms to the common logarithms.

In the above remarks concerning the process used by Prony in the calculation of his tables, it has been shown that the greatest part of the work is reduced to simple addition required by the application of what mathematicians call the method of differences. This immediately brings up the possibility of entrusting the preparation of the tables of logarithms to calculating machines, of the type called "for differences." This is not a matter of fiction, for a machine of this type invented by the Swedes, Schentz, father and son, and shown at the Universal Exposition in Paris in 1855, has been found adapted to such an operation. And not only does it effect the calculation of logarithms, but it also stamps the results as depressions in a lead plate after the method of stereotyping, calculating and stereotyping at the same time two and a half pages of tables in the same time that a good compositor would need to set up a single page. Through the liberality of a wealthy American merchant, Mr. Rathbone, this machine became the property of the Dudley Observatory at Albany, N. Y., and has there effectively served to calculate tables of which some examples were put on sale in Paris in 1858.

However invaluable the tables of logarithms may be to calculating humanity, they do not in themselves constitute the entire benefit derived from the ingenious invention of Napier. Indeed, scarcely had this invention come to light when it was transformed by the Englishman, Gunter, into the logarithmic scale, on which the functions, at least for certain numbers, are at distances from the origin proportional to the logarithms of these numbers. This simple scale of Gunter, a kind of graphic representation of Napier's table, was in its turn to become the source of a number of improvements in the organization of means by which the calculator could more and more simplify his task. It was in fact Gunter's scale which gave birth to the slide rules or calculating circles whose use is to-day so widely extended, of which the primitive type, conceived in 1652 by Oughtred, has since then, with various modifications in detail, multiplied in an infinite number of varieties.[1]

Combined with diverse mechanical means, such logarithmic circles have in their turn brought about the construction of machines to accomplish operations of a very different complication; such a one is that extraordinary machine for resolving algebraic equations of any degree whatever, designed about 20 years ago by M. Torrès-Quevedo, and which that ingenious Spanish scholar exhibited several months ago, among many other devices of his own invention, not less surprising, in the mechanical laboratory of the Sorbonne.

It is also from the logarithmic scale that Lalanne derived the idea of anamorphosis, announced in 1843, which has so notably contributed to the development of graphic methods of calculation and has been the origin of the new conceptions which gradually developed into what is to-day known as Nomography.

When we thus rapidly glance at the great multiplicity of results in practice and in theory which have sprung, from the invention of the Scotch lord in 1614, we come to realize that of all the achievements of human genius, not one has surpassed this in fecundity, and we can have only praise for the happy initiative which, as shown by the impressive celebration of its tercentenary, has led the public thought toward the source of so much progress.

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[1] On these methods and the different mechanical or graphic methods which have been devised for the simplification of numerical calculation, see the work of the author of the present article: "Le calcul simplifié par le procédés mécaniques et graphiques" (published by Gauthier-Villars).

MODERN VIEWS ON THE CONSTITUTION OF THE ATOM.[1]

By Prof. A. S. Eve,
McGill University.

At a meeting of the Royal Society of Canada held at Montreal, May, 1914, the writer gave by request a summary of recent work and ideas on the nature of the atom. The object was to concentrate, as clearly as possible, but not exhaustively, the results and opinions scattered through many different publications. Few men have time or opportunity to collect and analyze for themselves the large output bearing on this fascinating subject.

1. It may be well to call attention to the general bearing of the situation. Biologists are divided into three camps, vitalists, mechanists, and those who sit on the boundary fence. The mechanists believe that all phenomena relating to life are attributed to the action of physical and chemical processes only. The vitalists believe that life involves something beyond and behind these. Now those who investigate natural philosophy, or physics, are endeavoring with some fair initial success, to explain all physical and chemical processes in terms of positive electrons, negative electrons, and of the effects produced by these in the ether, or space devoid of matter.

If both the mechanists are right, and also the physicists, then such phenomena as heredity and memory and intelligence, and our ideas of morality and religion, and all sorts of complicated affairs are explainable in terms of positive and negative electrons and ether. All of these speculations are really outside the domain of science, at least at present.

2. It has been remarked by Poincaré that each fresh discovery in physics adds a new load on the atom. The conditions which the atoms have to explain may indeed be written down, but to do so is merely to make a complete index for all books on physics and chemistry in the widest sense.

3. In the early days of the kinetic theory of gases, now well established in its broad outlines, it was sufficient to regard the atom as a perfectly elastic sphere, and it is about a generation ago[2] that lead-

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[1] Reprinted by permission from Science, July 24, 1914.

[2] Young proved this in 1806, but his work was forgotten, until Rayleigh called attention to it in 1890. Phil. Mag., vol. 30, p. 474.

ing savants were triumphantly determining the effective radius as about 10^{-8} cm. (a convenient shorthand for the hundred millionth of a centimeter).

The discovery of electrons as the cathode rays of an electric discharge in an exhausted tube, and as the beta rays of radium, opened up new regions. It appears that negative electricity consists of electrons with their accompanying but unexplained effects in the ether. Electrons in motion produce magnetic fields. Their effective mass is about one eighteen hundredth part of that of a hydrogen atom, and their effective radius one hundred thousandth. The greatest known speed of electrons nearly approaches that of light.

The Zeeman effect, or separation of a single line in the spectrum by suitable magnetic fields into two or more lines, proved conclusively that the vibrations of negative electrons in the atom are the cause of the disturbances in the ether which we know as light.

4. The first scheme of an electronic atom, propounded by Sir Joseph Thomson, was a sphere of positive electricity of undefined character, within which revolved concentric rings of electrons in the same plane. There necessarily followed the simplicity of circular motion under a force to the center, proportional to the distance between the electron and the center of the atom.

5. Previous to this Lord Rayleigh had called attention to a serious anomaly. In a train of waves of a periodic character, the electric intensity E varies as the sine of nt, where t is the time and $2\pi/n$ is the period. As the equations involve the second differential of E, it appears inevitable that the square of n should appear in the law for spectral series. As a matter of fact there appears not the square of n, but n itself. It is desirable to be more explicit. If parallel light from a luminous source passes through a slit and a prism, together with suitable lenses, then the eye or photographic plate can detect a number of bright lines forming the spectral images of the slit for different colors, provided that the light is from luminous mercury vapor or hydrogen, or some such source. Many of these lines have been found to belong to one or more series crowding together toward the violet end. Balmer and Rydberg have found that the general type of formula for their frequency n is

$$n = N_0\left(\frac{1}{a^2} - \frac{1}{b^2}\right),$$

where N_0 is a universal constant called Rydberg's number, the same in value for all electrons of all atoms; and a and b are whole numbers or integers. We shall refer later to the importance of Rydberg's constant and of this magnificent generalization.

The trouble to which Rayleigh referred was first faced by Ritz in a startling manner. He imagined that there were inside the atom, placed end to end, a number of small magnets with an electron constrained to move in a circular path around the line of magnets. With this hypothesis he was able to account correctly for the above law for series of lines in the spectrum.

We may appreciate Poincaré's criticism—

> On a quelque peine à accepter cette conception, qui a je ne sais quoi d'artificiel.

Inasmuch as physicists endeavor to explain magnetism in terms of revolving electrons, there is a lack of simplicity, and there is an inconsistency, in introducing elemental magnets inside the atom. Nevertheless, it must be admitted that Weiss has found remarkable evidence for the conception of magnetons or elemental unit magnets, producing intramolecular fields reaching to millions of Gauss units, far transcending any produced by our most powerful electromagnets, and difficult to explain by revolving electrons.

Again to quote Poincaré—

> Qu' est-ce maintenant qu'un magnéton? Est-ce quelque chose de simple? Non, si l'on ne veut pas renoncer à l'hypothèse des courants particulaires d'Ampère; un magnéton est alors un tourbillon d'électrons, et voila notre atome qui complique de plus en plus.

Perhaps the hypothesis of Bohr, explained later, may overcome the difficulty, but for some time to come the more prudent will suspend judgment on the magneton.

Recently there has been nothing short of a revolution in physics. In certain domains, the leading workers and thinkers have deliberately abandoned the classical dynamics and electrodynamics, and made suppositions which are in direct opposition to these. This startling change may perhaps be justified by the fact that the famous laws and equations were based on large-scale experiments, so that they do not necessarily apply to conditions within the atom. Those who put forward and make use of the new hypotheses, men like Planck and Lorentz, Poincaré and Jeans, and others, appear to do so with reluctance, like a retiring army forced from one position to another. Others, like Rayleigh and Larmor, appear to regard the whole movement with misgivings, and some endeavor, like Walker and Callendar, to find a way out. There is a young school who go joyfully forward, selecting and suggesting somewhat wild hypotheses, and yet attaining an unexpected measure of success by their apparently reckless methods.

The main phenomena to which the new mechanics have been applied are the radiation within an inclosure, and the distribution of energy therein; the high speed of electrons ejected from matter by ultra-violet light, or by Röntgen rays, or by the gamma or penetrating rays from radioactive substances, or, as I suggest that we call them, from radiants; the atomic heat of elements, so admirably handled by Debye; the residual energy at low temperatures; and the constitution of the atom.

Space prevents us from considering more than the last of these.

The first step toward the new method was taken by Planck when he saw the necessity of explaining why the energy of short-wave radiation is some hundred millionth part of that demanded by classical dynamics. He made the supposition that energy is not indefinitely divisible, but he did not assume that it was atomic. He actually imagined that energy was emitted from oscillators in exact multiples of hn, where n is the frequency of the oscillation and h is a universal constant (Planck's) with a value 6.5×10^{-27} erg second. The magnitude of the energy quantum is thus proportional to the frequency.

This quantum hypothesis has spread like fire during a drought. It pervades the scientific journals. No physicist has pretended to explain or understand it, for, as Jeans says, the lucky guess has not yet been made. Nevertheless, it appears that "h" has truth underlying it, and that it has come to stay, for the applications of the quantum hypothesis have already achieved a great and unexpected measure of success. In the meantime it is necessary to proceed with caution, checking every theory by experiment, for there is no other criterion to guide the investigator, whether to hold to the old or try the new.

7. The first steps toward the idea of the modern or Rutherfordian atom rest on an experimental basis, and are not, therefore, open to suspicion.

Rutherford and Geiger found that when the alpha particles from a radiant, such as radium or polonium, met a thin gold leaf, the bulk of the alpha particles passed through with slight deflection, but about 1 in 8,000 bounced back, or returned toward the side of their source. Both large and small deviations of the alpha particles in passing through matter were satisfactorily explained by ordinary or Newtonian dynamics, with the law of repulsion inversely as the square of the distance between similar electric charges. One charged particle was the alpha particle with a positive charge twice as large, numerically, as that of an electron. The other charged particle was the nucleus of the atom of gold, and the magnitude of this charge was about ½A where A is the atomic weight of gold. This view was subjected to a searching series of experimental tests and emerged triumphant.

8. About this time C. T. R. Wilson skillfully obtained photographs of the mist-ladened, charged air molecules, marking the track of a recent alpha particle, in an expansion chamber. Some of these

photographs showed where a collision had occurred between the alpha particle and one of the heavier molecules of air. It immediately occurred to Sir Ernest Rutherford that a collision between an alpha particle and a lighter atom, such as hydrogen, would result in the nucleus of the latter being projected beyond the known range of the alpha particle. The point was put to the test by Marsden, and a complete justification of Rutherford's nucleus resulted. The hydrogen nuclei were found to produce scintillations on a zinc sulphide screen at a range about four times as great as that of the alpha particles. Some mathematical investigations by G. C. Darwin indicated that the alpha particle or nucleus of helium, and the hydrogen nucleus must have approached so close that their centers were but 1.7×10^{-13} centimeter apart. This affords further evidence of the extreme minuteness of the nucleus compared with the size of an atom (10^{-8} centimeter).

9. It may be well to recall at this point an interesting result of Barkla, obtained some years earlier, who showed from the scattering of Röntgen rays that the number of electrons in the atom must be about ½A, where A is the atomic weight. In the case of an uncharged atom, the positive charge on the nucleus must evidently balance the negative charges on the electrons revolving in orbits around that nucleus.

Thus we can form a clear mental picture of the general character of the atom. It is a miniature solar system. The sun is replaced by the positively charged nucleus. The planets, perhaps confined to one or more definite orbits or rings, are replaced by negative electrons revolving rapidly around the nucleus. The gravitational force is replaced by the electrical attraction between the positive nucleus and negative electrons.

10. A brilliant young Dane, Bohr, has gone a step further and suggested the structure of an atom capable of explaining the series of spectral lines. His work is remarkable as leading to excellent numerical verification. He assumes the Rutherfordian nucleus of electronic charge about half the atomic weight; he assumes that for every revolving electron in every atom the angular momentum is some exact multiple of Planck's constant $/2\pi$.

He further supposes that in a steady stationary orbit even a single electron does not radiate away energy. This is entirely contrary to classical electrodynamics. Furthermore he imagines that in passing from one state of stationary orbit to the next possible, there is homogeneous radiation of amount hn, where n is the frequency. This is of course Planck's assumption, and it is certainly unexplained, and probably not in accord with Hamilton's equations as deduced from Newton's laws. Nevertheless, any day we may learn why energy is emitted per saltum, and this mystery will vanish.

Now if you permit these somewhat arbitrary assumptions to Bohr, he can and does deduce, at least for the lighter atoms such as hydrogen and helium, the Rydberg formula for the spectral series. He finds:

$$n=\frac{2\pi^2me^4}{h^3}\left(\frac{1}{a^2}-\frac{1}{b^2}\right),$$

where n is the frequency; m, e, mass and charge of an electron; h is Planck's constant; a, b, are integers. The quantity before the bracket should equal the Rydberg number N_0, of observed value 3.29×10^{15}. Bohr's calculated value is 3.26×10^{15}, showing a most satisfactory agreement.

Bohr endeavors to account for the manner in which two hydrogen atoms form a molecule. Each atom has a nucleus of positive charge and a simple electron revolving around it. Their charges are equal and opposite. The nuclei of two such atoms repel each other. The revolving electrons of two atoms close together, if rotating in the same direction, constitute two parallel currents of electricity, and these attract one another and arrive in the same plane. It is easy to make a model on a whirling table with the nuclei on an upright rod, the electrons revolving like the governor balls of an engine. Bohr has gone further, and conceived a similar model of a water molecule with the two nuclei of hydrogen and one nucleus of oxygen in a straight line, with 10 electrons revolving in their zones around them. No doubt these suggestive schemes are somewhat speculative, but it is refreshing to find a first approximation to a dynamical scheme replacing the .old unsatisfactory electrostatic atoms, which probably did not approximate to the truth. Some of the formidable organic molecules must have a complexity which it may take generations of physicists to unravel.

11. One of the triumphs of mathematical physics was the forecast of Laue that crystal bodies have their atoms so distributed that Röntgen rays must be diffracted by these atoms in the same manner that closely ruled cross lines diffract visible light. This forecast and its rapid verification, enable the two Braggs, father and son, to measure with accuracy the wave lengths of Röntgen rays. While the waves of visible light are of the order 10^{-5} centimeter, those of Röntgen rays are of the order 10^{-8} centimeter, about one-thousandth of the former. The electromagnetic theory recognizes no intrinsic difference between the great waves of wireless telegraphy, several kilometers in length (10^6 centimeters), short electric waves, long heat waves, visible light (10^{-5} centimeter), ultra-violet waves, and Röntgen rays (10^{-8} centimeter).

The method of reflecting Röntgen rays from a rock-salt or another crystal has been applied by Moseley with marked success to the determination of the nucleus charges of the atoms of most of the elements. He bombarded the elements, one after the other, by electrons as cathode rays, reflected the resulting Röntgen rays from a crystal, and measured the wave-lengths of one or other of the principal (K or L, hard or soft) radiations.

In this manner he found

$$n = A(N - B)^2,$$

where n is the frequency of vibration, N the nucleus electronic charge, necessarily a whole number, and A and B are determined constants. In this manner he has found the atomic numbers N of all the known elements from aluminium 13 to gold 79. There appear to be but two or three elements not yet found by the chemists. These experimental results bear out well a view first propounded by van den Broek, that each element has an atomic number, an integer representing its place in the periodic table (H 1, He 2, Li 3, Be 4, Bo 5, C 6, and so forth). The atomic weight is not an exact integer, nor of such fundamental character as the atomic number. There will be further reference to this point later.

12. Rutherford has extended Moseley's method and results to the crystal reflection of the gamma rays from a radiant (Ra B), and determined the wave lengths of many lines, in particular of the two strongest. He has bombarded lead with Ra B rays and found the wave lengths of the radiation stimulated in the lead. He found that Radium B and lead gave the same spectrum, indicating that they have the same atomic number, 82. Hence he deduced the atomic numbers of all the radiants in the uranium-radium family. His results are worth repeating.

Radiant.	Rays.	Atomic No.	Atomic weight (about).	Radiant.	Rays.	Atomic No.	Atomic weight (about).
Uranium 1...........	α	92	238.5	Radium A...........	α	84	218.5
Uranium X 1........	β	90	234.5	Radium B...........	β	82	214.5
Uranium X 2........	β	91	234.5	Radium C...........	α, β	83	214.5
Uranium 2...........	α	92	234.5	Radium D...........	β	82	210.5
Ionium...............	α	90	230.5	Radium E...........	β	83	210.5
Radium..............	α	88	226.5	Radium F...........	α	84	210.5
Radium Em........	α	86	222.5	Lead................	.....	82	206.5 (207.1)

13. All of these results are in harmony with the wonderful advances in radiochemistry due to Soddy, Fajans, Von Hevesy, and others. It has been found that when a radiant emits an alpha particle or helium nucleus, the chemical properties of the newly formed radiant differ from the old. A fresh element is formed, a different valency results, and the new radiant, relative to the old, is two columns to the left in the periodic table. The atomic number has decreased 2 and the atomic weight about 4. But when a radiant ejects a beta particle or electron, again there is a new radiant with different valency and

chemical properties, but there is a move of one column to the right in the periodic table; a gain of one in the atomic number and no change in the atomic weight.

A brief example of the whole scheme applicable to all radiants is given below:

Column.			
IV.	V.	VI.	At. Wts.
Ur X 1 ⟶ 90, β	Ur X 2 ⟶ 91, β.	Ur 2 92, α	234.5
	↖	Ur 1 92, α	238.5

In the case of these radiants Ur 1 ejects an α particle and gives rise to Ur X 1. The latter and Ur X 2, respectively, emit a β particle.

It should be added that the short-lived product Ur X 2 or "brevium" was discovered by this theory, after it had been formulated from the known behavior of other radiants.

It will be seen that Uranium 1 and 2 are in the same column and have the same atomic number, but that their atomic weights differ by 4. Such substances have chemical properties so identical that they are called inseparables, or nonseparables, or isotopes, for they occupy the same place in the periodic table. Thus the old trouble of finding places in the periodic table for the 30 or 40 radiant elements has suddenly vanished. They may be superposed even when their atomic weights differ, if their atomic numbers are the same. The nuclear charges of isotopes must be identical, but the distribution of electrons may be different. Other examples of inseparables are lead, radium B, radium D, all 82; thorium and radiothorium; radium and mesothorium.

It must be further noted that the results of radiochemistry appear to require the presence of negative electrons in the nucleus itself. The expulsion of a β particle or one negative electron from the nucleus is equivalent to the gain of one positive electron, and involves a unit increase in the atomic number.

14. The last advance is the most important and far-reaching. There has been long search for the positive electron, and in vain; yet it seems likely that it has been under our eyes all the time. Since the hydrogen atom never loses more than a single electron, is it not possible, suggests Rutherford, that the nucleus of the hydrogen atom may be the positive electron?

The electromagnetic mass of an electron is $\frac{2}{3}\frac{e^2}{a}$ where e is the charge and a the radius. If the mass of the hydrogen nucleus is wholly electromagnetic, then its radius must be smaller than that of the electron (negative) as 1:1800, for that is the ratio of their masses, while their charges are equal and opposite. Hence we have

	Mass.	Diameter.
		Cm.
Atom	1	10^{-8}
Negative electron	1/1800	10^{-13}
Positive electron	1	10^{-16}

Rutherford cautiously remarks that there is no experimental evidence against such a supposition.

Those who wish to follow the matter deeper must refer to many articles in the Philosophical Magazine, several letters to Nature, Soddy's "Chemistry of the Radio-elements," Part II, and Perrin's "Les Atomes." The chief writers have been Rutherford, W. H. Bragg, W. L. Bragg, G. C. Darwin, Moseley, Broek, Bohr, Russell, Fajans, Soddy, Hevesy, Nicholson, and Marsden.

Much has yet to be done, and much to be revised, but that the first great forward strides have been taken in the right direction there can be little doubt.

GYROSTATS AND GYROSTATIC ACTION.[1]

By Prof. **Andrew Gray**, M. A., LL. D., F. R. S.

[With 10 plates.]

We are accustomed in daily life to handle nonrotating bodies, and their dynamical properties excite little attention, though it can not be said that they are commonly understood. It is different, however, with rotating bodies. These, when handled, seem to be endowed with paradoxical, almost magical, properties. I have here an egg-shaped piece of wood. I place it on the table and it rests, as we expect it to do, with its long axis horizontal. Our experience tells us that this is the natural and correct position of the body. But I set it spinning rapidly on the table, as you see, with the long axis horizontal, and you observe that after an apparently wobbling motion it erects itself so that its long axis is vertical. It was started spinning about a shortest axis, but the body has of itself changed the spin, and it is now turning about the long axis. In taking this position it has actually raised itself against gravity through a height equal to half the difference between the lengths of the long and short axes. This seems paradoxical, but the man who is in the habit of spinning tops knows that this is the proper position of the body; that it must stand up in this way when spinning rapidly on a rough horizontal plane.

This experiment may be performed at the breakfast table with an egg as the spinning body. But the egg must be solid within—that is, it must be hard-boiled; a raw or soft-boiled egg will not spin. Perhaps this is why Columbus did not adopt this method for his celebrated experiment; there may, of course, have been other reasons.

It is thus made clear that by causing a body to rotate rapidly we endow it with new and strange properties. Between a top when spinning and the same top when not spinning there is a difference which reminds us of that between living and dead matter; and this will strike us still more forcibly when we consider some more complicated cases of rotational motion. The top, the ordinary spinning top of the schoolboy, stands on its peg and "sleeps" in the upright position, in contempt of all the laws which govern statical equilibrium.

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[1] Reprinted by permission from pamphlet copy published by the Royal Institution of Great Britain. Lecture at the Weekly Evening Meeting, Friday, Feb. 14, 1913.

The experimental study of spinning tops is carried on by very small boys and a few more or less aged people. Somehow, but I think quite wrongly, a top is regarded as a toy suitable only for a child, and that kind of amusement is scarcely encouraged by the benevolent despots who so completely direct the games of boys at school. Among older boys there used to be a regular game in Scotland of "peeries," and some of you may have read Clerk Maxwell's poetical description of the Homeric contests which distinguished the sport.

The top as a plaything is despised; nevertheless it is a most important contrivance. The earth on which we live is a top, and a considerable range of astronomical phenomena are most easily explained by reference to the behavior of ordinary spinning tops. It is a top that directs the dirigible torpedo, that controls the monorail car, which may soon rise from the position of a small model to that of an important affair of practical railway engineering, and that in the gyrostatic compass gives a direction-pointer unaffected by the iron of the ship or the rolling and pitching of the vessel. Its properties (summed up in what we call gyrostatic action) have to be reckoned with in all swift-running machinery, such as fast-speed turbines and rotary engines of all kinds, especially if these drive flywheels or propellers. They affect very seriously the stability of aeroplanes and even of submarines, and I am very doubtful if aviators have yet become in sufficient degree instinctively alive to the dangers of sudden turning, such as those which are or used to be encouraged by the promoters of aviation displays in alighting competitions.

The man who has spun and studied tops and gyrostats appreciates as no one else can the extreme importance of properly balancing rotating machinery, and of avoiding gyrostatic action where such action is likely to interfere with the running of the machine as a whole.

The properties of a top are best studied in the gyroscope, or gyrostat, as it is better called. Here is a simple gyrostat, of the ordinary form sold in the toy shops, but with some important modifications to enable it to run for a long time at a high speed. It consists, as you see, of a heavy-rimmed metal disk or flywheel capable of rotation with but little resistance from friction on pivots held in sockets attached to a metal frame. Thus the flywheel may, by the quick withdrawal of a string wound round its axle, or in some other way, be set into rapid rotation in the frame, which in turn is mounted in various ways to show gyrostatic effects. But this ordinary form, as well as some others of a more pretentious character, suffers from the great disadvantage of having no means of maintaining the spin, and the continual renewal of the spin is a great nuisance.

I have here a gyrostat (fig. 1)[1] in which this drawback has been overcome by the simple and effective device of making the flywheel itself the rotor of a high-speed continuous-current electric motor. The ordinary gramme-ring armature is well adapted for this. It gives a wheel of great moment of inertia, or, as I call it, "spin inertia" (that is, the matter of the wheel is distributed so as to be on the whole as distant from the axis as possible), which can be run at high speed for a long time without trouble of any kind from bearings or contacts.

For my first experiments the motor gyrostat is set up, with the axis of the flywheel horizontal, in this mounting, which consists, as you see, of a fork perched on a pillar. Notice the possible motions, the freedoms, I may call them, of the arrangement. The flywheel can turn about its axle, the case can turn about the line of the pivots which carry it in the fork, and the fork about a vertical axis provided in the pillar. These three axles, which we shall number 1, 2, 3, are mutually at right angles and meet at the center of gravity of the movable system or gyrostat proper. When thus set up the gyrostat is said to be freely mounted.

With the flywheel at rest I push down on one side of the case, and immediately turning takes place, as we should expect, about the axis 2. Pushing down the other side of the case causes the instrument to turn about the axis 2 in the opposite direction. I grasp the fork in my hands and turn it about the axle 3 in either direction. Nothing unexpected happens; the gyrostat turns with the fork, its axis remaining horizontal throughout. Again, I grasp the pillar in my hands and turn it on the table, and you see that the friction of the axle 3 is sufficient to cause the fork and gyrostat to move round with the pillar. As before, the axis of the flywheel remains horizontal.

My assistant now causes a current of electricity to flow in the coils which form part of the flywheel and in the coils which surround the soft iron core of the magnet which is stationary within the ring. So far you can only tell that the flywheel is turning by the faint hum which its motion sets up. But when I repeat the operations which I have just performed on the nonrotating gyrostat, the behavior of the instrument is quite startlingly different. I push down on one side of the case as before; a resisting force is experienced, and the gyrostat turns, not visibly about the axle 2, but about 3, the vertical axis. So long as I maintain the tilting force so long does the resistance and this turning about the vertical persist. I withdraw the tilting force, and the turning motion ceases.

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[1] Figures on plates numbered consecutively.

Now I would direct attention to these rods with arrowheads, which are screwed to the gyrostat case. This curved one shows the direction in which the flywheel is spinning. The straight rods are intended to represent the spin momentum and the tilting action, respectively. Both are completely known when their amounts and their planes are known. The spin momentum is got by multiplying two numbers together, one representing the spin inertia of the wheel (which is greater the more the mass is placed in the rim), the other the speed of turning. The turning action or "couple" is also got by multiplying the force with which I push by the arm or leverage of the force about the axis. So then we represent these two by lines drawn at right angles to the two planes, making the lines of lengths to represent the two products. Standing on one side of the plane of the flywheel, you see it turning against the hands of a clock; standing on one side of the plane of the turning action which I apply, you observe that action tending to turn the body also against the hands of a clock. The two lines representing the two products drawn toward you from the two planes represent also the directions of the turning actions of the couples. For example, the direction of rotation of the flywheel being that shown by the curved rod, the line representing the spin momentum points outward from the side of the gyrostat to which the rods are attached. I call this the spin axis. The other line, representing the turning action which I applied, I call the couple axis.

Now, observe that I set the couple axis so as to point toward your left. I push down the side of the gyrostat nearest me, and you see that the spin axis turns toward the left. Again, I turn the couple axis so as to point to your right. When so placed it represents a turning action tending to depress the end of the axle of the flywheel that is nearer you. I apply such an action, and the spin axis turns toward your right. In both cases the spin axis turned toward the instantaneous position of the couple axis.

Now I set the couple axis vertical, pointing up. It represents a turning action tending to produce horizontal turning in the counterclock direction as seen from above. I apply such an action to the fork, when you see that the gyrostat turns the spin axis toward the upward direction. Finally, I set the couple axis vertical but pointing down, as in figure 1. It now represents a turning action tending to produce clockwise rotation as viewed from above, counterclock rotation as seen from below. I apply the action represented and the gyrostat turns the spin axis toward the downward direction.

These experiments may be summed up as follows: The flywheel is spinning about axis 1. Any attempt to tilt the gyrostat about axis 2 produces turning about 3; an attempt to tilt it about 3 produces turning about 2. This response of the body seems paradoxical, but

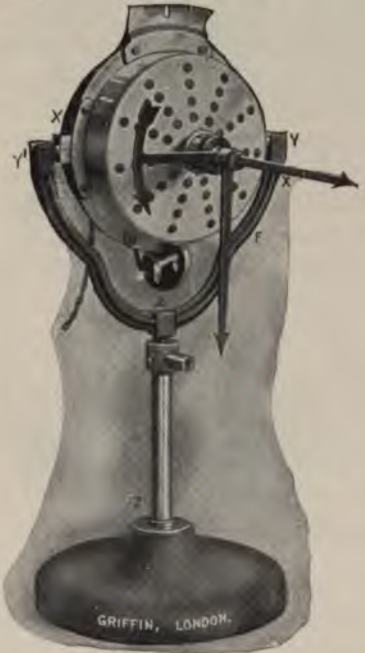

FIG. 1.—MOTOR-GYROSTAT IN "FORK AND PEDESTAL" MOUNTING.

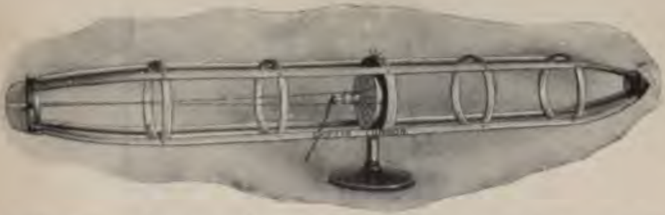

FIG. 2.—MOTOR-GYROSTAT MOUNTED TO DEMONSTRATE THE PRINCIPLE OF THE DIRIGIBLE TORPEDO.

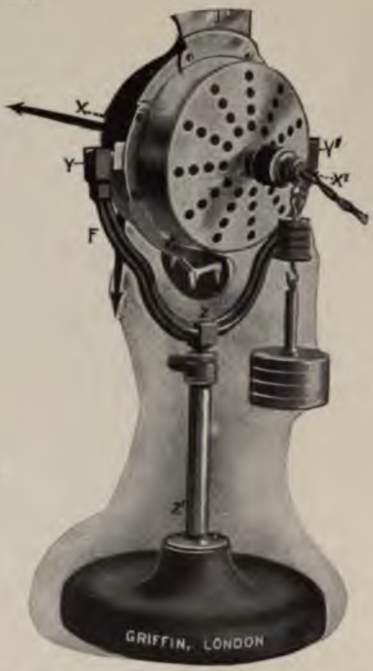

FIG. 3.—MOTOR-GYROSTAT IN PEDESTAL WITH WEIGHT ATTACHED.

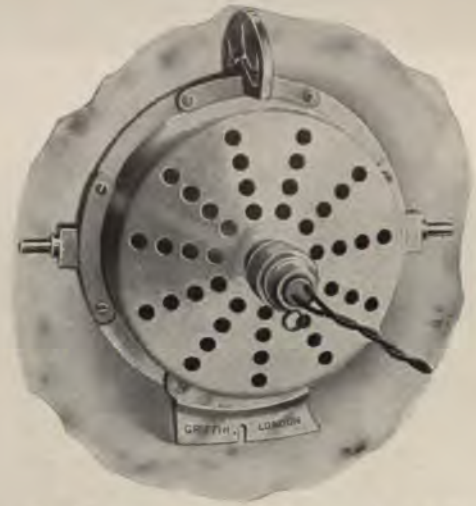

FIG. 4.—MOTOR-GYROSTAT BALANCING ON A SKATE.

in point of fact, and this is the secret of the whole affair, this turning of the body as a whole amounts to the production of spin momentum about the couple axis at exactly the proper rate. It is quite easy to prove this by the consideration, in the most elementary way, of the accelerations of the different particles composing the wheel.

The turning of the spin axis toward the couple axis is called a precessional motion, from a similar motion of the earth which produces the astronomical phenomenon called the precession of the equinoxes. The turning action, or couple, as I shall now call it, may be said to cause the flywheel to "precess" toward the couple axis. This relation of directions is very important, and should be kept always in mind.

If this turning response of the body, about an axis which we shall call 3, is prevented when turning about an axis 2, at right angles to 3, is changing the direction of the axis of a rotor—an axis 1, say, at right angles to 2 and 3—a preventing couple, usually called gyrostatic, about the axis 3, must be applied by the bearings to the axle of the rotor, and therefore an equal and opposite couple by the axle to the bearings. This couple, it is easy to prove, is equal to the product of the spin momentum and the angular speed at which the direction of the axis of the rotor is being changed. Thus the greater the moment of inertia of the rotor, or its angular speed, or the angular speed of the change of direction of the axis, the greater is the gyrostatic couple.

For example, the rotor of a dynamo, mounted on one of the decks with its rotor axis athwartship, applies, when the ship rolls, a couple to the bearings, the plane of which is parallel to the deck, and which consists of a forward force on one bearing and a sternward force on the other. These forces are reversed with reversal of the direction of rolling, so that an alternating force is applied to each bearing, tending to shear it off the deck. Thus if the bearings are at all loose, the axle will knock alternately on the front and back of each bearing.

Similarly the axle of the rotor of a fore-and-aft turbine, when the ship pitches, applies a force to port to the bearing at one end, and a force to starboard at the other end, which forces are reversed when the direction of the pitching motion is reversed. When the course is being changed the forces of the gyrostatic couple are applied to the top of one bearing and the bottom of the other.

Now, returning to the pillar gyrostat, and putting the flywheel in rapid rotation, I turn the pillar round on the table. I have turned, as you see, the base round through one revolution, and throughout the turning motion the axle of the flywheel has remained pointing in the same direction. The friction at the axle about which I have turned the pillar, which, you will remember, was sufficient to carry the gyrostat round when there was no spin, is now quite insufficient to cause any serious change of position of the gyrostat. Only a very small couple producing precession acted.

This experiment illustrates the principle of permanence of direction of the axis of rotation, in the absence of a couple producing precession, the principle on which depend the gyrostatic compass and the self-directing torpedo. Carried within the body of the torpedo is a fast-spinning gyrostat, and at the instant at which the torpedo leaves the impulse tube this gyrostat is mounted freely with its axis coincident with that of the torpedo; that is, pointed, so to speak, exactly along the "cigar." Any turning of the torpedo body sidewise brings about a relative shift between the gyrostat and torpedo axes, and this shift brings into operation a vertical rudder at the stern of the torpedo. If the nose of the torpedo turns to port, the rudder steers the craft to starboard, and vice versa.

Here (fig. 2) is a skeleton frame representing a torpedo. It is mounted on a vertical axle, and carried on pivots within the structure is one of our motor gyrostats. At the stern of the frame is a small rudder, and this is connected by means of cords to the gyrostat. I set the flywheel in rotation. When, as I do now, I turn the nose of the torpedo to port, the rudder steers to starboard; when I turn the nose to starboard the rudder steers the craft to port.

The case of the pedestal gyrostat is provided with a hook at one extremity of the axis (see fig. 3). The effect of hanging a weight on this hook is to apply a couple tending to cause turning about the axis 2; that is, which would produce such turning if the flywheel were not spinning. But the wheel is spinning, and the visible actual turning is about the axis 3. Observe also that the wheel is rotating comparatively slowly, and that the precessional motion is great. I increase the speed of the flywheel and the gyrostat precesses more slowly. I replace the weight by a larger one, and for the same spin the precessional motion is greatly increased. Thus for a given applied couple the faster the spin the slower the precessional motion, and for a given spin the greater the couple the faster the precessional motion.

Now, while the weight is in position and the gyrostat precessing about the axle 3, I attempt to hurry the precessional motion, and immediately the gyrostat turns about the axis 2 so as to rise against gravity. I try to delay the precession, and again the gyrostat turns about the axis 2, but now so as to descend under gravity.

Without being aware of it people are constantly meeting with examples of gyrostatic action in daily life. A child expert in trundling a hoop causes it to turn its path to the right or left, by striking it a blow at the top with the hoop stick, the effect of which the ordinary person would suppose, if he thought about it, should be to make the hoop to fall over to the right or the left. A bicyclist riding without holding the handles leans over to the right if he wants to steer the bicycle to the right, and to the left if he wants to steer to the left. And if he feels himself falling over to right or left he turns the handles instinctively so as to turn the bicycle to that side, when the machine resumes the upright position. In the bicycle, however, the spin of the wheels is not the most important action to be taken account of.

The gyrostatic action in the bicycle is much more marked in a motor machine, for in that a massive flywheel rotates in the same direction as the wheels. As the bicycle turns a corner it is constrained to precess, and a couple is needed to produce this precession of the rotating parts quite apart from that required to turn the rest of the machine. This the rider applies by leaning over to the inside of the turn, and leans over more than he would have to if the flywheel were not there or were not rotating.

Good examples of gyrostatic action are given by paddle and turbine steamers. A paddle steamer is steadier in a cross sea than a screw steamer of the same size. This is due in part to the gyrostatic action of the paddle wheels, which, but for their comparatively slow speed of rotation, would form a compound gyrostat of considerable power. For this gyrostat the spin momentum may be conveniently represented by a line drawn from the steamer toward the port side. A couple tending to tilt the steamer over to starboard is represented by a line drawn toward the bow, and a couple tending to tilt the steamer to port by a line drawn toward the stern. Hence, if the steamer heels over to starboard, her bow, in consequence of gyrostatic action, precesses to starboard, but the starboard wheel, becoming somewhat more deeply immersed, uses more power and exerts a turning influence to port. Thus the steersman has less difficulty in keeping the vessel on a straight course. But if the vessel be turned by the rudder, say to port, the vessel will by gyrostatic action be slightly heeled over to starboard, and the starboard wheel, being more deeply immersed, will assist the turning action of the rudder. When, however, the steamer falls off her course, to port or starboard, the gyrostatic action causes the correcting action applied by the rudder to be resisted. Though the gyrostatic action of the wheels is not very great, calculation shows that it is enough to produce an appreciable variation in the immersion of the wheels.

The gyrostatic action of the flywheel in a motor car is of some practical interest. The flywheel is placed with its plane athwart the car—that is, with the axis, so to speak, fore and aft. It rotates in the clockwise direction as viewed by an observer behind the car. ? The effect of turning a corner to the left gives a gyrostatic couple throwing the weight of the car more on the back wheels; turning to the right throws the weight more on the front wheels. The forces applied by the ground to the front wheels are diminished in the former case and increased in the latter. There is danger, therefore, of the steering power of the car being interfered with, if the corner is taken at too great a speed.

As a final example, we take an aeroplane. Here the rotor of the engine and the propeller together form a compound gyrostat of considerable power. As the bearings are fore and aft, the action is similar to that of the flywheel of the motor car. Turning horizontally in one direction gives rise to the gyrostatic couple tending to make the aeroplane dive, turning the opposite way sets up a couple which makes the aeroplane rear up in front. If the aeroplane is kept horizontal, such couples have to be balanced by stresses in the framework. These considerations show that sudden turning of aeroplanes should, if possible, be avoided. Maneuvers calling for such turning are accompanied by very considerable danger. No doubt aviators are aware of the existence of gyrostatic action, but there is considerable haziness in people's minds as to its direction in the various possible cases. The peculiar properties of rotating bodies need not, of course, be understood theoretically by aviators, though it is well to know something about them. But the aviator, like a person walking or swimming, must know instinctively what to do in an emergency, and what motions must be avoided. The gyrostatic action he has to contend with lies hid, as it were, until he tries some new and violent maneuver; and then it brings him to grief.

I now pass on to some special experiments which can be carried out with these motor gyrostats. First, take one or two old experiments,[1] which are more effectively performed with these fast-running instruments. Here is a skate attachment (fig. 4) on which I place the gyrostat after its speed has been adjusted to the moderate value of about 6,000 revolutions per minute. The plane of the flywheel is inclined to the vertical, and you see that the top does not fall down, but precesses round on the table. I increase the inclination and the precession becomes more rapid. Now I attempt to hurry the precession and the gyrostat stands up erect; I try to resist the precession and the gyrostat falls over.

I mount the gyrostat with its wheel horizontal over a flexible support, in the present case a universal joint (fig. 5). Without rotation the instrument would fall over at once; but you see that it stands stably erect when the flywheel is spinning, and has a precessional motion when disturbed from the upright position.

Again, here is a two-stilt support. (Fig. 6.) One of the stilts is held by a long socket, at one side of the case, and may be regarded

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[1] See Thomson & Tait's Natural Philosophy, sec. 345^x et seq.

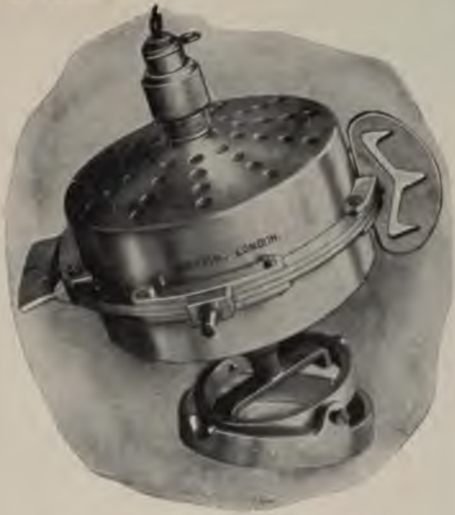

FIG. 5.—MOTOR-GYROSTAT ON GIMBALS.

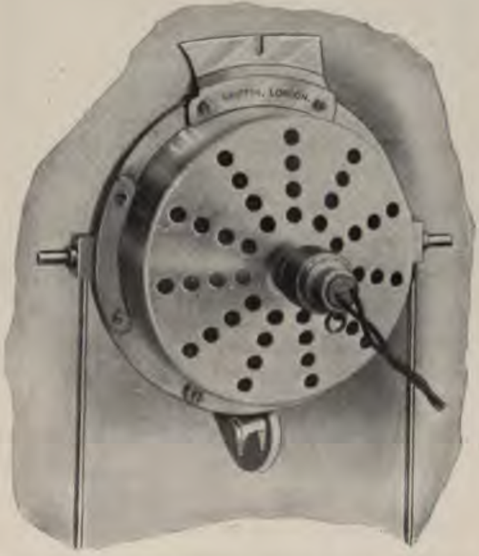

FIG. 6.—MOTOR-GYROSTAT BALANCING ON STILTS.

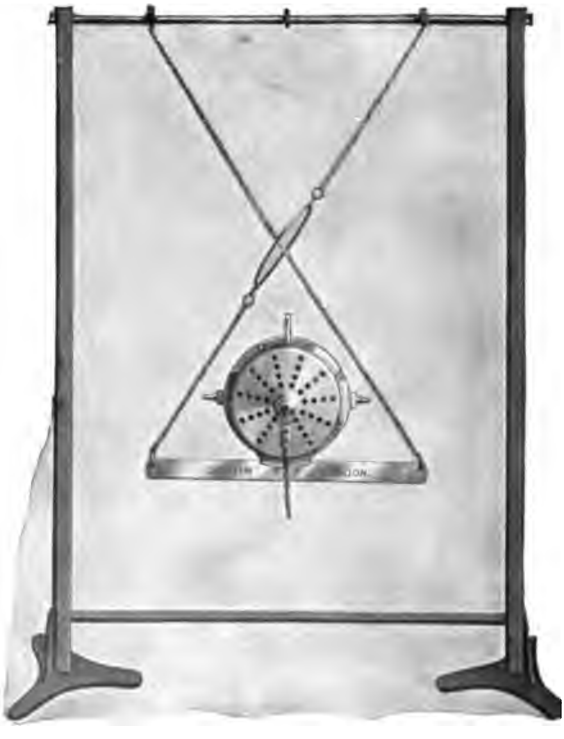

FIG. 7.—MOTOR-GYROSTAT ON CROSSED BIFILAR SUPPORT.

as rigidly attached. The other stilt is simply a bit of wire pointed at both ends; one end rests on a table, the other, the upper end, rests loosely in a hollow in the upper side of this projecting piece attached to the case. The gyrostat is thus supported between two stilts, one fixed, the other quite loose, and its axis is at right angles to the plane of these when the arrangement stands upright. It would be hard to devise a more unstable support. You see that there is no possibility of making the arrangement stand up without spin. But you see, on the other hand, that there is a fair amount of stability with the flywheel spinning if the arrangement is allowed to oscillate, or, as one might say, wriggle backward and forward, horizontally.

In the next experiment (due originally, I have been told, to the late Prof. Blackburn) the gyrostat is rigidly clamped to this metal bar, which, as you see, is hung by two chains attached to its ends. (See fig. 7.) The chains have been crossed by passing one through a large ring in the middle of the other. I turn the gyrostat so that the chains and the rim of the case are in the vertical plane. You observe that the arrangement is one of instability. The gyrostat has perfect freedom to fall over toward you or toward me. Further, in consequence of the crossing of the chains the gyrostat is unstable as regards motion about a vertical axis. The arrangement is thus doubly unstable without rotation.

I now set the flywheel into rapid rotation, arrange the instrument as before, and leave it to itself, when, as you observe, it balances with great ease.

I now repeat the experiment with the chains uncrossed. Here there is only one instability without rotation, and the gyrostat falls over. An important point to be observed is that the rotation will stabilize two nonrotational instabilities, but not one. In point of fact, a system possessing nonrotational freedoms, all of which are unstable, can be stabilized if the number of freedoms is even, but not if the number is odd.

A general explanation of the experiment just performed may be given as follows: Starting with the bar, gyrostat rim, and chains (crossed) in one vertical plane, we may suppose the gyrostat to fall over slightly. In consequence of the tilting couple introduced the gyrostat precesses so that its axis turns in a plane which is nearly horizontal. The chains now get slightly out of the vertical, and at once a couple hurrying the precessional motion is brought to bear on the gyrostat, which, in consequence, erects itself into the vertical position. The couple does not retard, but hurries the precession because the bars are crossed. This holds for both directions in which it is possible for the gyrostat to fall over. Again, suppose starting with the rim, bar, and chain in the same vertical plane, the chains get out of the vertical. There is now a couple brought to bear on the gyrostat tending to turn its axis in a horizontal plane. In consequence the gyrostat tilts over on the bar—in other words, it has a precessional motion about a horizontal axis in the plane of the flywheel. This brings into action a couple due to gravity, which is such as to hurry the last-mentioned precessional motion; the horizontal motion is opposed and reversed, and with the reversal the gyrostat regains the upright position. This holds for both directions in which the bar tends to turn in consequence of the crossed chains. The result is complete stability.

Similar explanations are applicable to the other cases of motion you have seen.

I now suspend the gyrostat from the horizontal beam by means of this chain terminating in a hook (fig. 8), which engages in a central recess of the rim attachment. The chain carries a ball-bearing race. I place the gyrostat with its axis horizontal and leave it to itself. The center of gravity of the gyrostat lies vertically below the hook, and under those conditions there is no couple tending to tilt the instrument. I transfer the hook to one of the side recesses, set the gyrostat so that its axis is horizontal, and leave it to itself, when, instead of falling down, it turns its axis in a plane which is nearly horizontal. If I delay the precessional motion the gyrostat descends; if I accelerate the precession the gyrostat ascends. I transfer the hook to the opposite side recess, place the gyrostat so that its axis is horizontal, and again let go. The gyrostat precesses as before, but in the opposite direction. Again I hurry the precession, and again the gyrostat rises; again I delay the motion, and the gyrostat descends.

In these experiments, when the hook engages in either of the side recesses there is a couple due to gravity tending to produce angular momentum in a vertical plane. The axis of spin momentum turns toward an instantaneous position of the couple axis at right angles to it, at angular speed, ω, say. If μ be the spin momentum, and the top has been properly started, angular momentum about the couple axis is being produced at rate $\mu\omega$ by this turning, and this is equal to the moment of the couple. The precessional moment remains at the value required to give just the rate of production of angular momentum corresponding to the couple. This is the point generally missed in popular explanations of the gyrostatic action.

It is important to notice, however, that, as these experiments are usually carried out, the precession, though apparently steady to the eye, is not, strictly speaking, perfectly steady. There is a very slight alternate rise and fall of the axis. To get quite steady motion, the top must not be simply spun and then left to itself; it must be started with the right amount of precession.

I now place the gyrostat within this wooden tray. (Fig. 9.) The pivots carried by the rim of the gyrostat engage on bearings provided in the tray, and these are on a level with the center of gravity of the whole. I hold the tray so that its plane is horizontal, and carry it round in a horizontal circle. Nothing happens. Still holding the tray so that its plane is horizontal, I carry it round in a horizontal circle in the reverse direction. The gyrostat immediately turns a somersault and is thereafter stable. If I reverse the direction of rotation of the tray, again the gyrostat turns a somersault and remains again quiescent.

The gyrostat is stable, with its axis vertical, so long as the direction of spin coincides with that in which the tray is being turned. If this latter direction is reversed, the gyrostat turns a somersault so as to render the two directions coincident. It appears as if the arrangement had a will of its own, and refused to be carried round against its direction of spin.

The theory of this experiment is very instructive. Both cases are represented by one differential equation, but in one case there is a real period of vibration about the vertical; in the other the period is mathematically unreal, and the gyrostat axis moves farther away from the vertical. No better illustration of the two cases of the equation can be found.

The behavior of the tray gyrostat is exemplified also in the gyrostatic compass. A heavy and rapidly rotating flywheel is mounted so that its axis is maintained horizontally by means of an elastic support. Under these conditions the equilibrium position of the flywheel under the horizontal component of the turning velocity of the earth (which corresponds to the turning of the tray) is arranged to be that in which the axis of rotation points due north and south. If time permitted, I should be glad to make an experiment with a carefully balanced motor gyrostat, which would not only show the turning of the earth under the gyrostat, but enable the rate of turning to be measured.

I would now direct your attention to this motor gyrostat, which forms the bob of an ordinary compound pendulum. (Fig. 10.) The tube carrying the gyrostat is attached, by means of a universal joint, to the apex of a triangular stand, made of telescope tubing. The gyrostat is attached to the lower end of its supporting tube, by means of a special cap provided with spring contact pieces, to allow the current to be led into the motor, and the flywheel is free to rotate about an axis coincident with the rod. Screwed to the lower side of the gyrostat is a pen, which presses lightly on a card placed below.

We have now the pendulum rod in the vertical position. I draw the pendulum to one side and let go, when you see that it vibrates to and fro, and the pen traces out a straight line on the paper. The flywheel has as yet no spin. I start the flywheel revolving, draw the pendulum to one side, and let go, either from rest, or with a certain amount of sidelong motion, when you observe that the pen describes a flower-shaped path. (Fig. 11.) The path is shown for different amounts of sidelong motion. The peculiar appearance of these curves is due to the rapid falling off of amplitude produced by friction.

When the flywheel is revolving there are, in general, two couples acting on the pendulum, one due to gravity, the other due to gyrostatic action. At an instant at which the axis of the gyrostat is vertical the former couple is zero, and the latter one is a maximum, for at that instant the angular velocity with which the axis of the gyrostat is changing direction is greatest. When the pendulum is at one extremity of its swing the former couple is a maximum, and the latter one is zero. At that instant the deflection of the bob from the vertical is a maximum, and it is at rest, or is moving sidewise, according to the mode of starting, except in so far as the initial conditions have been interfered with by friction. By this relation of the couples the form of the path can be explained.

Another mode of motion is possible which has a very intimate connection with the theory of vibrations of light-emitting molecules in a magnetic field, as indeed I pointed out here several years ago in a Friday evening discourse.[1] The bob can be made to move in a circle about the vertical through the point of support either with or against the direction of rotation of the flywheel. The two periods are different, and the motions correspond to the circularly polarized light of two distinct periods, which molecules, situated in a magnetic field, are found to emit. Thus the gyrostatic pendulum gives a dynamical analogue of the cause of the Zeeman effect.

In 1907 Herr Otto Schlick introduced a method of employing a gyrostat to counteract the rolling of a vessel at sea. The gyrostat is carried on bearings placed athwart the ship. These bearings are in line with the flywheel, and a weight is attached to the frame of the gyrostat in a position in line with the axis. It will be seen that when the ship is on even keel the gyrostat rests with its axis vertical, and with the weight vertically below the center of gravity of the flywheel. Heeling of the ship in one direction causes the gyrostat to precess in one direction on the bearings on which it is mounted; heeling in the other direction causes precession in the opposite direction, and couples resisting the rolling motion are brought to bear on the ship. The device may be employed in two ways. In the first place, if the bearings on which the frame of the gyrostat is carried within the ship are smooth, the effect of the gyrostat is to resist the rolling force of the waves, and to bring about a lengthening of the free period of the ship, according to a mathematical theory

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[1] See Nature, Apr. 13, 1899, and Aug. 24, 1899.

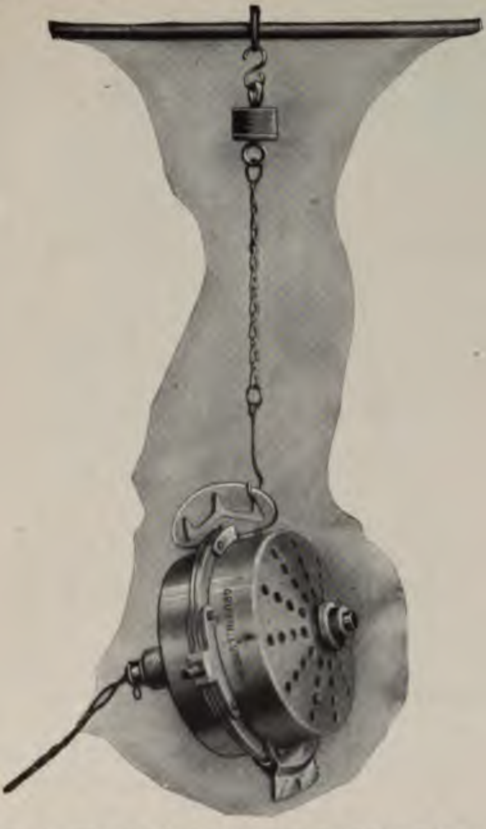

FIG. 8.—MOTOR-GYROSTAT PRECESSING ON CHAIN SUPPORT.

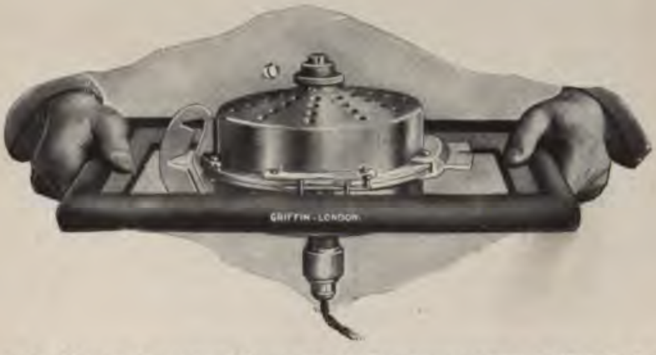

FIG. 9.—MOTOR-GYROSTAT MOUNTED TO DEMONSTRATE THE PRINCIPLE OF THE GYROSTATIC COMPASS.

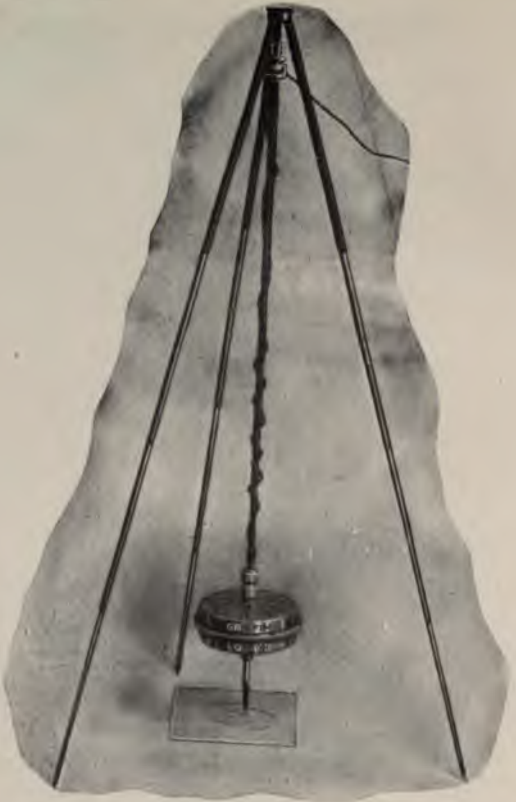

FIG. 10.—MOTOR-GYROSTAT FITTED UP AS A GYROSTATIC PENDULUM.

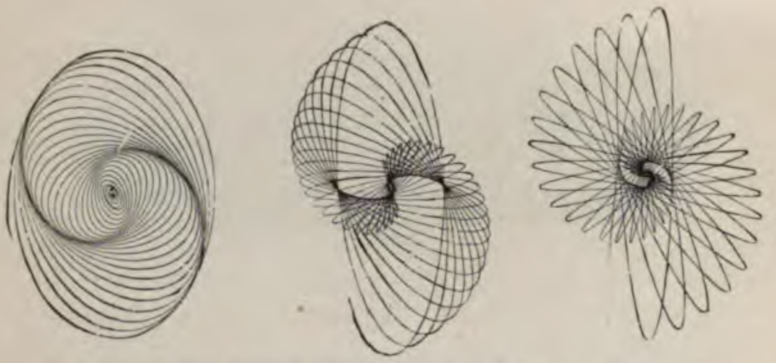

FIG. 11.—SOME CURVES OBTAINED WITH THE GYROSTATIC PENDULUM.

which, when put in the proper way, is really very simple. Excessive rolling of a ship is due to the cumulative action of the waves, and such cumulative action is only possible where the period of the ship and that of the waves are of about the same order. A large ship has a very long period, and synchronism of the ship and the waves is impossible. The effect of introducing a gyrostatic control, operated in the manner just described, is to endow the small ship with the period of a very large one.

In the second mode of operating the gyrostat, friction is introduced at the bearings on which the frame of the gyrostat is mounted. With this addition the ship is forcibly prevented from excessive rolling. In the trials of the device it was found that, with the control in operation, the angle of roll of the ship did not exceed 1° in a cross sea which produced a total swing of 35° when the control was out of action. It is interesting to notice that, contrary to the opinions which were expressed when the device was first suggested, the preventing of the rolling of a ship does not result in the waves breaking over her; a ship controlled by a gyrostat is, I believe, a dry one.

I have here a motor-gyrostat fitted within a skeleton frame representing a ship. (Fig. 12.) The frame is mounted on two bearings arranged on wooden uprights, and may be made to oscillate on these bearings, so as to imitate the rolling of a ship in a cross sea. The frame of the gyrostat is mounted on two bearings placed athwart the frame, and a weight is attached to the outside of the case in a position in line with the axis of the flywheel. The center of gravity of the gyrostat is in line with the bearings. A clip device is provided which allows the gyrostat to be clamped to the skeleton frame, and provision is made whereby a graded amount of friction may be applied at one of the bearings.

I now set the skeleton frame vibrating with the flywheel at rest. You observe the period. I start the motor gyrostat, and repeat the vibrations, with the gyrostat clipped to the frame. The ship rolls precisely as before. I free the gyrostat from the frame, and again set the ship rolling, when you see that not only is the period vastly increased, but the rolling motion is quickly wiped out.

When the gyrostat is clipped to the frame it produces no effect upon the rolling motion. The couples opposing the rolling motion arise from the precessional motion, and hence the gyrostat must be given freedom to precess. In this connection it is interesting to observe that in 1870 it was proposed by Sir Henry Bessemer to obtain a steady cabin for a cross-channel steamer by placing it on a gyrostat with its axis vertical and supported on fore and aft trunnions. This plan was bound to fail. The dependence of the effect on freedom of the axis to precess, in a direction which is not that of rolling, was not understood. We now see that the object would have been attained by supporting the cabin on fore and aft trunnions and mounting the gyrostat, within the cabin, on trunnions placed athwart the ship.

Here is a monorail top of new design (figs. 13–14.) The frame on stilts represents the car, and mounted on pivots placed across the frame is a gyrostat. Carried by a rod fixed to the frame of the gyrostat, and in line with the axis of the flywheel is a weight. When the frame is placed on the table so that the legs and axis of the gyrostat are vertical, with the weight above the flywheel, the arrangement is doubly unstable without rotation; the system of gyrostat and weight is usually mounted on the pivots, and the entire structure is unstable about the line of contact of the feet with the table. When the flywheel is rotating, however, the top balances on the table. The two nonrotational instabilities have been stabilized.

I now place the top on the table with the legs and axis of the flywheel vertical, but with the weight below the gyrostat. The arrangement is unstable. Here there is only one instability without rotation, and the result is instability with or without rotation.

Here is a stilt-top similar to the one just shown, but provided with wheels adapted to engage on a stretched wire. You observe the remarkable balancing power of the arrangement.

In this top (fig. 15) a gyrostat is pivoted within a structure which represents a tight-rope balancer. The structure terminates in wheels adapted to engage on the wire. Attached to the gyrostat are two arms, and carried by these is a light rod weighted at both ends. My assistant spins the flywheel and places the structure upon the wire with the legs vertical and the pole horizontal. The top, as you observe, balances on the wire. If the top tilts over on the wire toward me, the gyrostat precesses in the direction which carries the pole over toward you, and vice versa. That is, if the balancer begins to fall over to one side it immediately puts over the pole to the other side. The action is exactly that of a tight-rope acrobat.

The rider of a bicycle keeps the machine upright by operating the handle bar. If the machine tilts over to the left the rider turns the handle bar to the left, and the forward momentum of the bicycle and rider, aided by the gyrostatic action of the wheels (a relatively small factor in this case) results in the erection of the machine. Similarly, if the machine tilts to the right the front handle bar of the machine is turned to the right.

Here I have a small bicycle of the old-fashioned "high" type, provided with a gyrostatic rider. When the gyrostat is spinning rapidly you observe that the top is completely stable. The gyrostat operates the front wheel, just as does the rider on the ordinary bicycle.

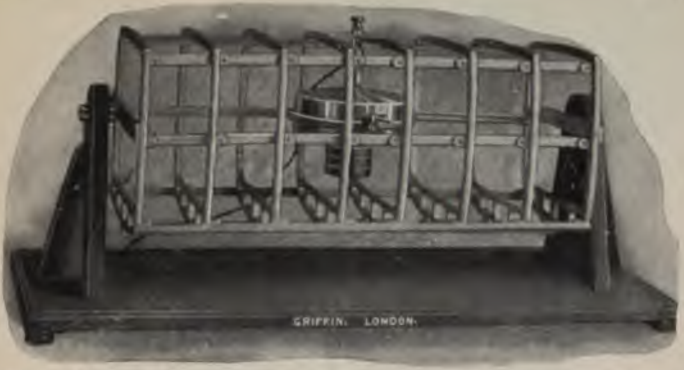

FIG. 12.—MOTOR-GYROSTAT FITTED UP TO DEMONSTRATE SCHLICK'S METHOD OF STEADYING A SHIP IN A CROSS SEA.

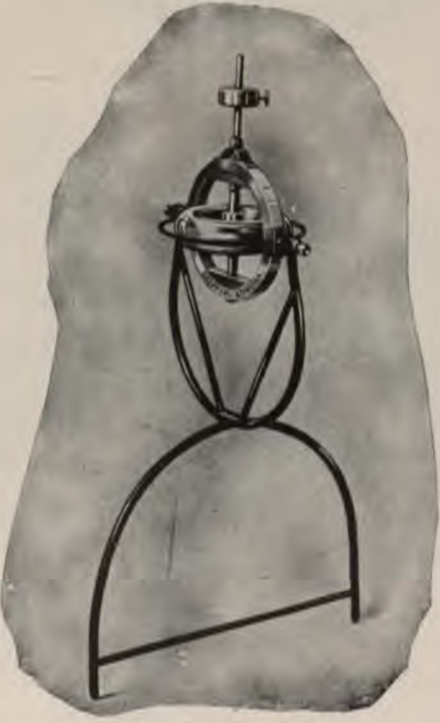

FIG. 13.—NEW MONORAIL-TOP.

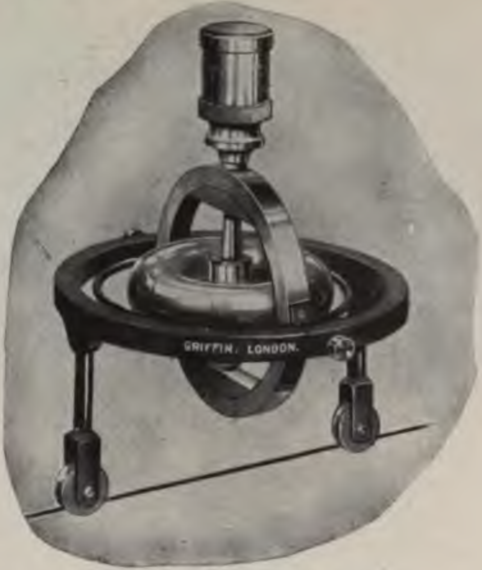

FIG. 14.—MONORAIL-TOP ON WIRE.

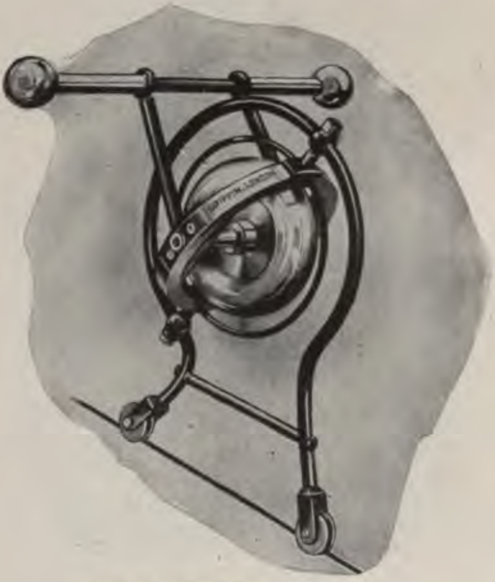

FIG. 15.—POLE-BALANCING TOP.

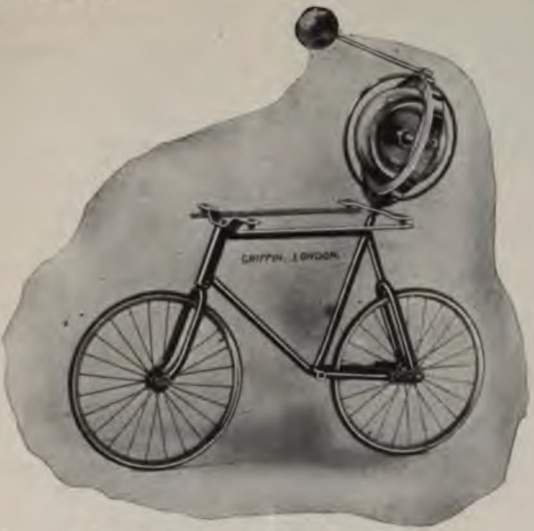

FIG. 16.—GYROSTATIC BICYCLE RIDER.

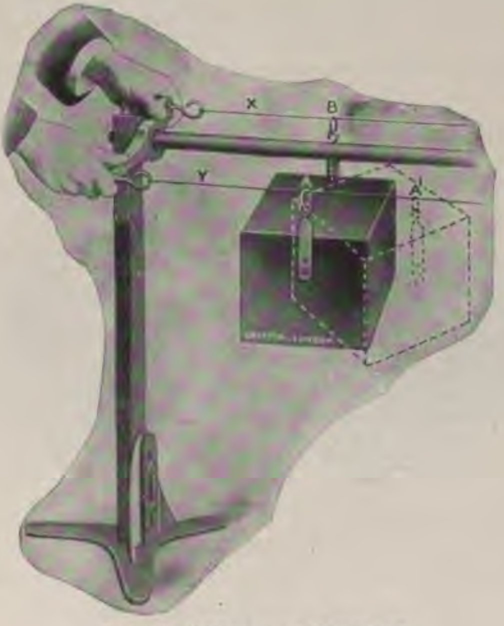

FIG. 17.—"WALKING" GYROSTAT.

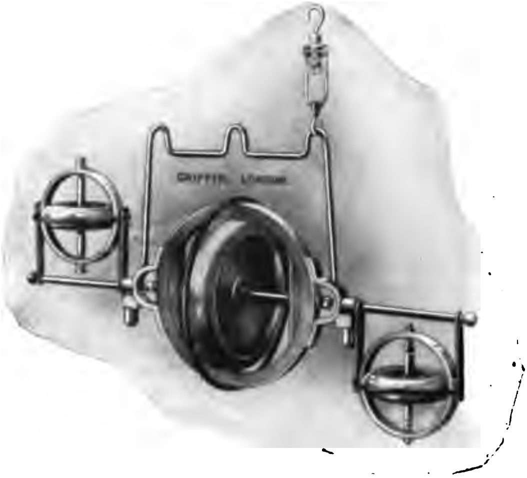

FIG. 18.—ACROBATIC TOP.

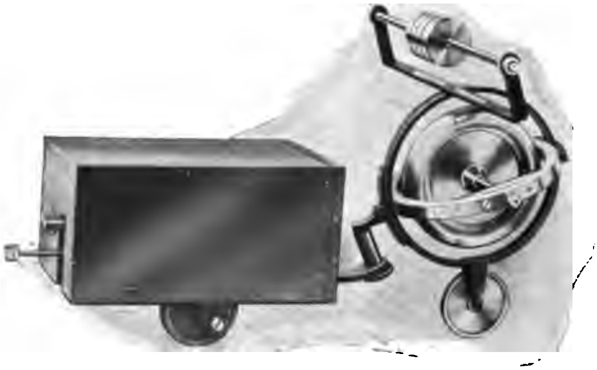

FIG. 19.—MOTOR-CAR.

Again, here is a small safety bicycle provided with a gyrostatic rider. (Fig. 16.) In this case the gyrostat is mounted above the back wheel, and is connected by arms to the handle bar of the front wheel. The action is the same as in the other model.

The tops I have shown you are very interesting from the fact that in each case the gyrostat not only detects but sets about correcting any tendency of the top to fall over. They behave as if they possessed both a nervous and a muscular system.

I have also here a gyrostat which can be made to progress in space by a reciprocating motion—in fact, a walking gyrostat. (Fig. 17.) The gyrostat is suspended by two chains from two horizontally stretched wires. The wires are carried by a wooden frame, which is mounted, as you see, on two trunnions carried by wooden uprights. The chains attached to the arms of the gyrostat terminate in two rings, and these are threaded on the stretched wires.

The gyrostat is spun and replaced on the wires. When the frame is tilted to and fro on the trunnions, the gyrostat walks "hand-over-hand" along the wires. By the tilting of the frame the weight of the gyrostat is thrown alternately on each of the chains, and in consequence of the precessional motion the gyrostat moves along, carrying the chains with it.

At present the spin is great, and therefore the precessional motion is small. The gyrostat proceeds with a slow and stately motion. As time goes on the spin falls off, and the rate of walking increases, until finally the gyrostat literally runs along the wires, with considerable loss of dignity. When the gyrostat is inclosed in a box, or within an acrobatic figure, the behavior seems very mysterious.

Here is still another form of acrobatic top, consisting of a large gyrostat, the axis of which is horizontal, and two small ones, with axes vertical, mounted, one on each side of the large one, on sleeves threaded on a horizontal bar, as shown in figure 18. My assistant spins the flywheel of the large gyrostat, which is then suspended by means of a string and hook from the upper bar of the frame. At present the center of gravity of the gyrostat is vertically below the hook, and under these conditions there is no precessional motion. He now spins the two small gyrostats and attaches them to the large one. Each small gyrostat is carried by two sleeves which are threaded on a horizontal bar. The hook is now transferred to one of the side recesses provided in the upper bar of the large gyrostat, and the system is left to itself, when it turns round in azimuth. One of the small gyrostats throws itself up and balances on the bar. The experiment is repeated with the hook engaging in the other side recess, when you observe that the small gyrostat which previously occupied the lower position now rises into the upright one, and the gyrostat which occupied the upright position now occupies the lower one.

This top admits of a large variety of designs. It is easy to imagine a gyrostatic circus rider performing balancing feats on the back of a gyrostatic horse!

I conclude with a gyrostatic model (fig. 19) which depends for its action upon an entirely novel and practical method of operating a gyrostat or gyrostats. The method has a very large variety of applications, into which I shall not enter at present. It is here shown applied to a motor car. The car runs on two wheels in tandem; it can be set to run either in a straight path or a path curved in either direction. The arrangement includes two parts connected by a vertical or nearly vertical hinge. Each is supported on a single wheel. The front part carries a gyrostat with axis horizontal (in this case), the afterpart contains the propelling mechanism. A quasi-gravitational field of force is produced by the propeller behind acting through the hinge, and the construction is such that there is true stability, not the quasi stability, accompanied by continually increasing gyrostatic oscillation, which obtains in many other cases.

STABILITY OF AEROPLANES.[1]

By Orville Wright, B. S., LL. D.

The subject of "stability of aeroplanes" is too broad to permit of a discussion of all of its phases in one evening. I shall, therefore, confine myself more particularly to a few phases of the fore-and-aft or longitudinal equilibrium. Although in learning to fly the beginner finds most difficulty in mastering the lateral control, it is his lack of knowledge of certain features of the fore-and-aft equilibrium that leads to most of the serious accidents. These accidents are the more difficult to avoid because they are due to subtle causes which the flyer does not at the time perceive.

A flying machine must be balanced in three directions—about an axis fore and aft in its line of motion, about an axis extending in a lateral direction from tip to tip of the wings, and about a vertical axis. The balance about the lateral axis is referred to as fore-and-aft or longitudinal equilibrium; that about the fore-and-aft axis as lateral equilibrium; and that about the vertical axis is generally referred to as steering, although its most important function is that of lateral equilibrium.

If the center of support of an aeroplane surface would remain fixed at one point, as is practically the case in marine vessels and in balloons and airships, equilibrium would be a simple matter. But the location of the center of pressure on an aeroplane surface changes with every change in the angle at which the air strikes the surface. At an angle of 90° it is located approximately at the center of the surface. As the angle becomes less, the center of pressure moves forward. On plane surfaces it continues to move forward as the angle decreases until it finally reaches the front edge. But on cambered surfaces the movement is not continuous. After a certain critical angle of incidence is reached, which angle depends upon the particular form of the surface, the center of pressure moves backward with further decrease in angle until it arrives very close to the rear edge. At angles ordinarily used in flying, angles of 3° to 12°, the travel of the center of pressure is in this retrograde movement and is located, according to the angle of incidence, at points between

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[1] Presented at the stated meeting of the Franklin Institute held Wednesday, May 20, 1914, when Dr. Wright received the Franklin Institute's Elliott Cresson Medal in recognition of the epoch-making work accomplished by him in establishing on a practical basis the science and art of aviation. Reprinted, by permission, from the Journal of the Franklin Institute, Philadelphia, September, 1914.

30 per cent and 50 per cent back of the front edge of the surface. The location of the center of pressure on any given surface is definitely fixed by the angle of incidence at which the surface is exposed to the air.

The placing of the center of gravity of the machine below its center of support appears, at first glance, to be a solution of the problem of equilibrium. This is the method used in maintaining equilibrium in marine vessels and in balloons and airships, but in flying machines it has the opposite of the desired effect. If a flying machine consisting of a supporting surface, without elevator or other means of balancing, were descending vertically as a parachute, the center of gravity vertically beneath the center of support would maintain its equilibrium. But as soon as the machine begins to move forward the center of pressure, instead of remaining at the center of the surfaces, as was the case when descending vertically, moves toward that edge of the surface which is in advance. The center of gravity being located at the center of the surface and the center of pressure in advance of the center of the surface, a turning moment is created which tends to lift the front of the machine, thus exposing the surfaces at a larger angle of incidence and at the same time to a greater resistance to forward movement. The momentum of the machine, acting through its center of gravity below the center of forward resistance, combines with the forward center of pressure in causing the surface to be rotated about its lateral axis. The machine will take an upward course until it finally comes to a standstill. The rear edge of the surface will now be below that of the front edge and the machine will begin to slide backward. The center of pressure immediately reverses and travels toward the rear edge of the surface, which now in the backward movement has become the front edge. The center of gravity again being back of the center of pressure, the advancing edge of the surface will be lifted as before, and the pendulum effect of the low weight will be repeated. A flying machine with a low center of gravity, without rudders or other means to maintain its equilibrium, will oscillate back and forth in this manner until it finally falls to the ground.

It will have been observed from the foregoing that the equilibrium in the horizontal plane was disturbed by two turning moments acting about the lateral horizontal axis of the machine; one produced by the force of gravity and the lift of the surface acting in different vertical lines, and the other by the center of momentum and the center of resistance acting in different horizontal lines.

It is evident that a low center of gravity is a disturbing instead of a correcting agent. The ideal form of flying machine would be one in which the center of gravity lies in the line of the center of resistance to forward movement and in the line of thrust. In practice this is not always feasible. Flying machines must be built to land safely as well as to fly. A high center of gravity tends to cause a machine to roll over in landing. A compromise is therefore adopted. The center of gravity is kept high enough to be but a slight disturbing factor in flight and at the same time not so high as to interfere in making safe landings.

The three forces acting on an aeroplane in the direction of its line of motion are the thrust of the propellers, the momentum or inertia of its weight, and the resistance of the machine to forward travel. If traveling in any other than a horizontal course, a component of gravity in the line of motion will have to be reckoned with. When these forces are exerted in the same line, with the centers of thrust and momentum acting in the opposite direction to that of the center of resistance, a variation in the quantity of any one, or of all, of these forces will not in itself have a disturbing effect on the equilibrium about the lateral horizontal axis. But these forces in the ordinary flying machine do not act in the same line. Usually the center of thrust is high, in order to give proper clearance between the propellers and the ground; the center of gravity is low, to enable the machine to land without danger of being overturned; and the center of resistance is usually between the centers of thrust and gravity. When a flying machine is traveling at uniform speed the propelling forces exactly equal the resisting forces. In case the thrust of the propellers is diminished by throttling the motor, the momentum of the machine acting below the center of resistance carries the lower part of the machine along faster than the upper part, and the surfaces thus will be turned upward, producing a greater angle and a greater resistance. The same effect is produced if the machine be suddenly struck by a gust of wind of higher velocity from in front. The thrust of its propellers will be temporarily slightly decreased, the resistance due to the greater wind pressure will be increased, and the momentum of the machine (the center of gravity being low) will in this case also turn the surfaces upward to a larger angle. While these variations in the forces acting in the horizontal line have of themselves a certain amount of disturbing effect, yet it is from the changes of incidence which they introduce that one encounters the greatest difficulty in maintaining equilibrium.

The two principal methods used in preserving fore-and-aft equilibrium have been, first, the shifting of weight so as to keep the center of gravity in line with the changing center of lift; and, second, the utilization of auxiliary surfaces, known as elevators, to preserve the position of the center of pressure in line with a fixed center of gravity. The first method has been found impracticable on account of the impossibilty of shifting large weights quickly enough. The second method is that used in most of the flying machines of to-day.

Flying machines of this latter type should have their auxiliary surfaces located as far as possible from the main bearing planes, because the greater the distance the greater is the leverage and consequently the smaller the amount of surface required. The auxiliary surfaces are usually placed either in front or in the rear of the main supporting surfaces, since they act with greater efficiency in these positions than when placed above or below.

With a view to high efficiency, no part of either the main surfaces or the auxiliary surfaces should be exposed on their upper sides in a way to create downward pressures. One pound of air pressure exerted downward costs as much in propelling power as 2 pounds of downward pressure produced by actual weight carried. This is due to the fact that the total pressure on an aeroplane is not vertical, but approximately normal to the plane of the surface. This pressure may be resolved into two forces, one acting in a line parallel with the direction of travel, and the other at right angles to the line of travel. One is termed "lift" and the other "drift." With a given aeroplane surface, the drift and lift for any given angle of incidence always bear a definite ratio to one another. This ratio varies from 1 to 12, to 1 to 1, according to the angle of incidence and the shape of the surface. On an average it is about 1 to 6, so that the thrust required of the propeller in the ordinary flying machine is approximately one-sixth of the weight carried. When traveling on a horizontal course the lift is vertical and is exactly equal to the total weight of the machine and load. This load may be real weight, or it may be partly real weight and partly downward pressures exerted on parts of the surfaces. For every pound of weight carried, a thrust of approximately one-sixth pound is required. If, however, instead of real weight a downward air pressure is exerted on some part of the machine, this downward pressure must be overcome by an equal upward pressure on some other part of the machine to prevent the machine from descending. In this case the horizontal component of the one pound downward pressure will be about one-sixth pound, and the horizontal component of the compensating upward pressure also will be about one-sixth pound, making a total of one-third pound required in thrust from the propellers, as compared with one-sixth pound thrust required by one pound actual weight carried. It is, therefore, evident that the use of downward air pressures in maintaining equilibrium is exceedingly wasteful, and, as far as possible, should be avoided. In other words, when the equilibrium of an aeroplane has been disturbed, instead of using a downward air pressure to depress the elevated side an upward pressure should be utilized to elevate the low side. The cost in power is twice as great in one case as in the other.

total P

The dynamically less efficient system of downward air pressures *is used* to some extent, however, on account of its adaptability in producing more or less inherently stable aeroplanes. An inherently stable aeroplane may be described as one in which equilibrium is maintained by an arrangement of surfaces, so that when a current of air strikes one part of the machine, creating a pressure that would tend to disturb the equilibrium, the same current striking another part creates a balancing pressure in the opposite direction. This compensating or correcting pressure is secured without the mechanical movement of any part of the machine.

The first to propose the use of this system for the fore-and-aft control of aeroplanes was Penaud, a young French student, who did much experimenting with model aeroplanes in the seventies of the last century. His system is used only to a slight extent in the motor-driven aeroplanes of to-day, on account of its wastefulness of power and on account of its restriction of the maneuvering qualities of the machine.

Penaud's system consists of a main bearing surface and a horizontal auxiliary surface in the rear fixed at a negative angle in relation to the main surface. The center of gravity is placed in front of the center of the main surface. This produces a tendency to incline the machine downward in front, and to cause it to descend. In descending the aeroplane gains speed. The fixed surface in the rear, set at a negative angle, receives an increased pressure on its upper side as the speed increases. This downward pressure causes the rear of the machine to be depressed till the machine takes an upward course. The speed is lost in the upward course, the downward pressure on the tail is relieved, and the forward center of gravity turns the course again downward. While the inherently stable system will control a machine to some extent, it depends so much on variation in course and speed as to render it inadequate to meet fully the demands of a practical flying machine.

In order to secure greater dynamic efficiency and greater maneuvering ability, auxiliary surfaces mechanically operable are used in present flying machines instead of the practically fixed surfaces of the inherently stable type. These machines possess the means of quickly recovering balance without changing the direction of travel and of maneuvering with greater dexterity when required. On the other hand, they depend to a greater extent upon the skill of the operator in keeping the equilibrium. It may be taken as a rule that the greater the dynamic efficiency of the machine and the greater its possibilities in maneuvering, the greater the knowledge and skill required of the operator.

If the operator of a flying machine were able to "feel" exactly the angle at which his aeroplane meets the air, 90 per cent at least of all aeroplane accidents would be eliminated. It has been the lack of this ability that has resulted in so large a toll of human lives.

Instruments have been produced which indicate closely the angle of incidence at which the machine is flying, but they are not in general use. Nor does the average flier realize how exceedingly dangerous it is to be ignorant of this angle. Most of the fliers are aware that "stalling" is dangerous, but do not know when they really are "stalling."

A flying machine is in great danger when it is flying at its angle of maximum lift. A change either to a smaller or a larger angle results in a lesser lift. There is this important difference, however, whether the angle be increased or decreased. While a smaller angle gives less lift, it also has less drift resistance, so that the machine is permitted to gain speed. On the other hand, the larger angle gives not only less lift but encounters a greater resistance, which causes the speed of the machine to be rapidly checked, so that there is a double loss of lift—that due to angle and that due to a lesser speed.

The maximum lift is obtained in most flying machines at some angle between 15° and 20°. If the machine be gliding from a height with the power of the motor throttled or entirely turned off, and the operator attempts to turn it to a level course, the speed of the machine will soon be reduced to the lowest at which it can support its load. If now this level course be held for even only a second or two, the speed and the lift will be so diminished that the machine will begin to fall rapidly.

The center of pressure on a cambered aeroplane surface at angles greater than 12° to 15° travels backward with increase of angle of incidence, so that when a machine approaches the "stalled" angles the main bearing surfaces are generally carrying practically all of the weight and the elevator practically none at all. Under these conditions the main surfaces fall more rapidly than does the rear elevator. The machine noses downward and plunges at an exceedingly steep angle toward the earth. This plunge would tend to bring the machine back to normal speed quickly were the machine flying at its usual angle of incidence. But at the large angles of incidence the drift is a large part of the total pressure on the surfaces, so that, although plunging steeply downward, speed is recovered but slowly. The more the operator tries to check the downward plunge by turning the elevator, the greater becomes the angle of incidence, and the greater the forward resistance. At ordinary stalled angles the machine must descend at an angle of about 25° with reference to the horizontal in order to maintain its speed. If the speed be already below that necessary for support, a steeper angle of descent will be required, and considerable time may be consumed before supporting speed can be recovered. During all this time the machine is plunging downward. If the plunge begins at a height of less than 200 or 300 feet, the machine is likely to strike the ground before the speed necessary to recover control is acquired.

The danger from "stalling" comes in the operator attempting to check the machine's downward plunge by turning the main bearing surfaces to still larger angles of incidence, instead of pointing the machine downward, at a smaller angle of incidence, so that the speed can be recovered more quickly. It is safe to say that fully 90 per cent of the fatal accidents in flying are due to this cause. Most of the serious ones occur when, after long glides from considerable heights, with the power of the motor reduced, an attempt is made to bring the machine to a more level course several hundred feet in the air. The machine quickly loses its speed and becomes "stalled." All of us who have seen the novice make a "pancake" landing have seen the beginning of a case of "stalling" which might have been fatal had it taken place at a height of 100 or 200 feet.

The greatest danger in flying comes from misjudging the angle of incidence. If a uniform angle of incidence were maintained, there would be no difficulty in fore-and-aft equilibrium. As has already been stated, for any given surface and any given angle of incidence the position of the center of pressure is fixed. Under these conditions, if the center of gravity were located to coincide with the center of pressure and a uniform angle of incidence maintained, the machine would always be in equilibrium.

It is in accordance with this principle that experiments the past year have brought about a considerable advance in the development of automatic stability. A small horizontal wind vane is so mounted on the machine as to ride edgewise to the wind when the machine is flying at the desired angle of incidence. In case the machine varies from the desired angle, the air will strike the vane on either its upper or lower side. The slightest movement of the vane in either direction brings into action a powerful mechanism for operating the controlling surfaces.

If the wind strikes the vane on the underside, as would be the case when the machine takes a larger angle of incidence, the elevator is turned to cause the machine to point downward in front till the normal angle is restored. If the air strikes the vane from above, a smaller angle of incidence is indicated, and an opposite action on the elevator is produced. In this system no particular angle of the machine with the horizontal is maintained. It is the angle at which the air strikes the aeroplane surface that is important. If the vane is set at an angle of 5° with the main supporting surfaces, and the machine is traveling on a level course, increasing the power of the motor will cause it to begin taking on more speed. But as the lifting effect of an aeroplane surface is the product of two factors—its speed and its angle of incidence—any increase in speed will produce a greater lift and cause the machine to rise. The machine will now be turned upward, with the surfaces meeting the air at an angle of 5°. On the contrary, if the power of the motor be reduced or entirely turned off, the machine will immediately begin to decrease in speed, requiring a larger angle of incidence for support. But as soon as the angle begins to increase the air will strike the regulating vane on the underside and the elevator will be turned, pointing the machine downward till the component of gravity in the direction of travel becomes sufficient to maintain the normal speed. In this case the planes will be inclined downward with reference to the horizontal. It is evident that a machine controlled by regulating the angle of the machine with reference to the impinging air is not liable to the dangers of "stalling" already described.

Several other methods of maintaining fore-and-aft equilibrium automatically have been proposed. One utilizes the force of gravity acting on a pendulum or a tube of mercury; the other, the gyroscopic force of a rapidly revolving wheel. In both of these systems the angle of the machine is regulated with reference to the horizontal, or some other determined plane, instead of with the angle of the impinging air.

In the case just referred to, in which the power of the motor was suddenly turned off while traveling on a level course, with these systems, the planes would be maintained at their original angle with the horizontal without any regard to the angle of incidence. The machine would continue forward till, through the loss of momentum, its speed would become so reduced and its angle of incidence so great that it would be exposed to the dangers of diving.

The pendulum and mercury tube have other serious faults which render them useless for regulating fore-and-aft equilibrium. If the machine suddenly meet with a greater resistance to forward travel, either as a result of change in direction or of meeting a stronger gust of wind from in front, and its speed be ever so slightly checked, the pendulum will swing forward and instead of turning the machine downward, so as to maintain the normal speed, will cause the machine to be inclined upward in front and thus further increase its forward resistance.

The pendulum has proved itself an exceedingly useful device, however, in regulating the lateral stability of aeroplanes. In this case the effects of momentum and centrifugal force act on the pendulum in the proper direction to produce desired results.

I believe the day is near at hand when the flier will be almost entirely relieved of the work of maintaining the equilibrium of his machine, and that his attention will be required only to keeping it on its proper course and in bringing it safely in contact with the ground when landing.

THE FIRST MAN-CARRYING AEROPLANE CAPABLE OF SUSTAINED FREE FLIGHT—LANGLEY'S SUCCESS AS A PIONEER IN AVIATION.

By A. F. ZAHM, Ph. D.

[With 8 plates.]

It is doubtful whether any person of the present generation will be able to appraise correctly the contributions thus far made to the development of the practical flying machine. The aeroplane as it stands to-day is the creation not of any one man, but rather of three generations of men. It was the invention of the nineteenth century; it will be the fruition, if not the perfection, of the twentieth century. During the long decades succeeding the time of Sir George Cayley, builder of aerial gliders and sagacious exponent of the laws of flight, continuous progress has been made in every department of theoretical and practical aviation—progress in accumulating the data of aeromechanics, in discovering the principles of this science, in improving the instruments of aerotechnic research, in devising the organs and perfecting the structural details of the present-day dynamic flying machine. From time to time numerous aerial craftsmen have flourished in the world's eye, only to pass presently into comparative obscurity, while others too neglected or too poorly appreciated in their own day subsequently have risen to high estimation and permanent honor in the minds of men.

Something of this latter fortune was fated to the late Secretary of the Smithsonian Institution. For a decade and a half Dr. Langley had toiled unremittingly to build up the basic science of mechanical flight, and finally to apply it to practical use. He had made numerous model aeroplanes propelled by various agencies—by India rubber, by steam, by gasoline—all operative and inherently stable. Then with great confidence he had constructed for the War Department a man flier which was the duplicate, on a fourfold scale, of his successful gasoline model. But on that luckless day in December, 1903, when he expected to inaugurate the era of substantial aviation, an untoward accident to his launching gear badly crippled his carefully and adequately designed machine. The aeroplane was repaired, but not again tested until the spring of 1914—seven years after Langley's death.

Such an accident, occurring now, would be regarded as a passing mishap; but at that time it seemed to most people to demonstrate the futility of all aviation experiments. The press overwhelmed the inventor with ridicule; the great scientist himself referred to the accident as having frustrated the best work of his life. Although he felt confident of the final success of his experiments, further financial support was not granted and he was forced to suspend operations. Scarcely could he anticipate that a decade later, in a far away little hamlet, workmen who had never known him would with keenest enthusiasm rehabilitate that same tandem monoplane, and launch it again and again in successful flight, and that afterwards in the National Capital it should be assigned the place of honor among the pioneer vehicles of the air.

When in March, 1914, Mr. Glenn H. Curtiss was invited to send a flying boat to Washington to participate in celebrating "Langley Day,"[1] he replied, "I would like to put the Langley aeroplane itself in the air." Learning of this remark Secretary Walcott, of the Smithsonian Institution, soon authorized Mr. Curtiss to recanvas the original Langley aeroplane and launch it either under its own propulsive power or with a more recent engine and propeller. Early in April, therefore, the machine was taken from the Langley Laboratory and shipped in a box car to the Curtiss Aviation Field, beside Lake Keuka, Hammondsport, N. Y. In the following month it was ready for its first trial since the unfortunate accident of 1903.

The main objects of these renewed trials were, first, to show whether the original Langley machine was capable of sustained free flight with a pilot, and, secondly, to determine more fully the advantages of the tandem type of aeroplane. The work seemed a proper part of the general program of experiments planned for the recently reopened Langley Aerodynamical Laboratory. It was, indeed, for just such experimentation that the aeroplane had been given to the Smithsonian Institution by the War Department, at whose expense it had been developed and brought to completion prior to 1903. After some successful flights at Hammondsport the famous craft could, at the discretion of the Smithsonian Institution, either be preserved for exhibition or used for further scientific study. To achieve the two main objects above mentioned, the aeroplane would first be flown as nearly as possible in its original condition, then with such modifications as might seem desirable for technical or other reasons.

Various ways of launching were considered. In 1903 the Langley aeroplane was launched from the top of a houseboat. A car supporting it and drawn by lengthy spiral springs ran swiftly along a track, then suddenly dropped away, leaving the craft afloat in midair with

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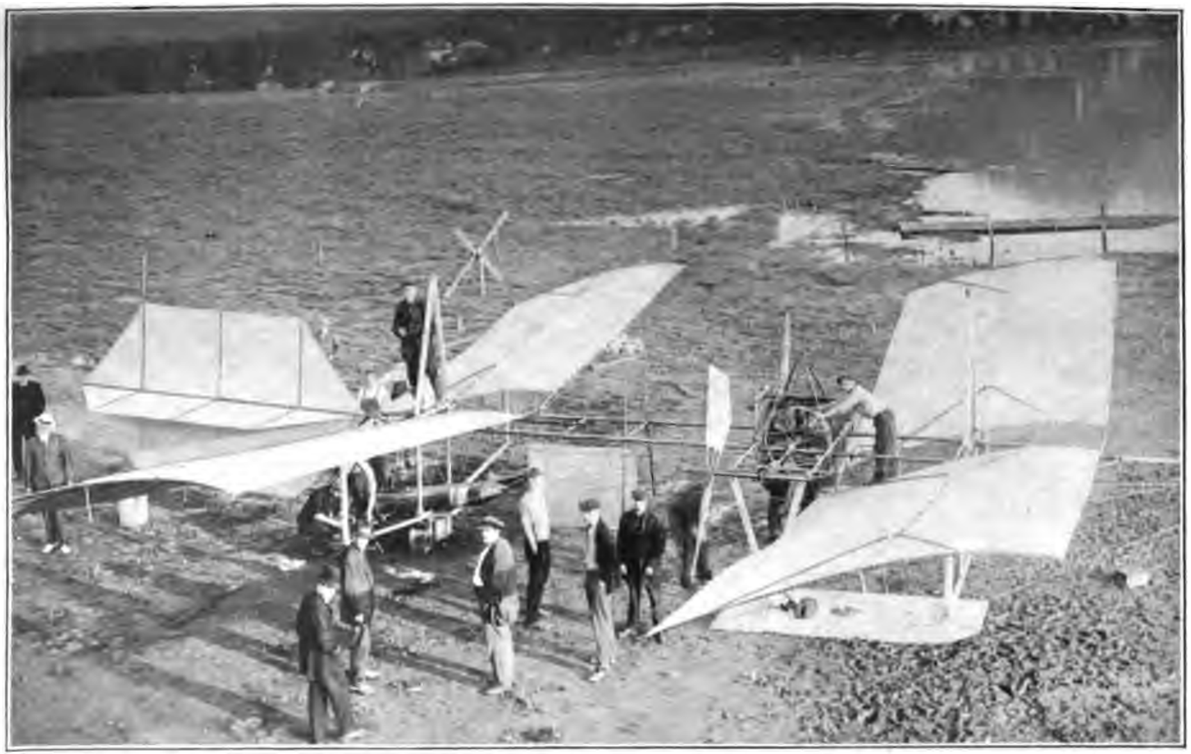
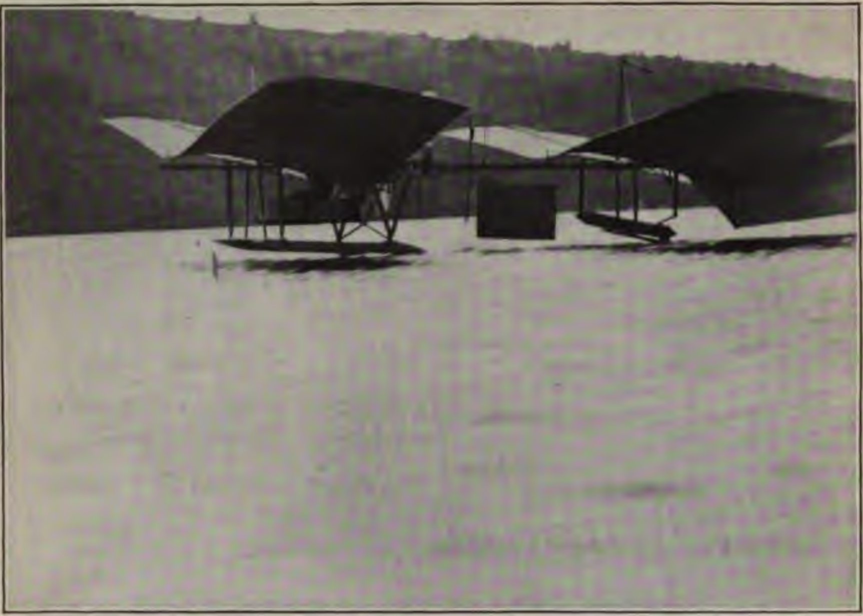
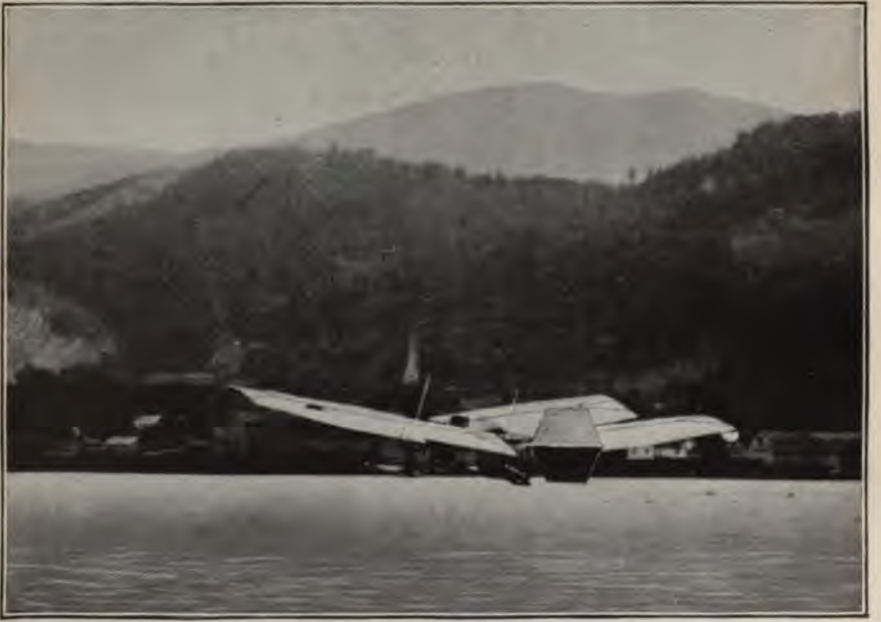
[1] May 6, the anniversary of the famous flight of Langley's steam model aeroplane in 1896, is known in Washington as "Langley Day," and has been celebrated with aerial maneuvers over land and water.



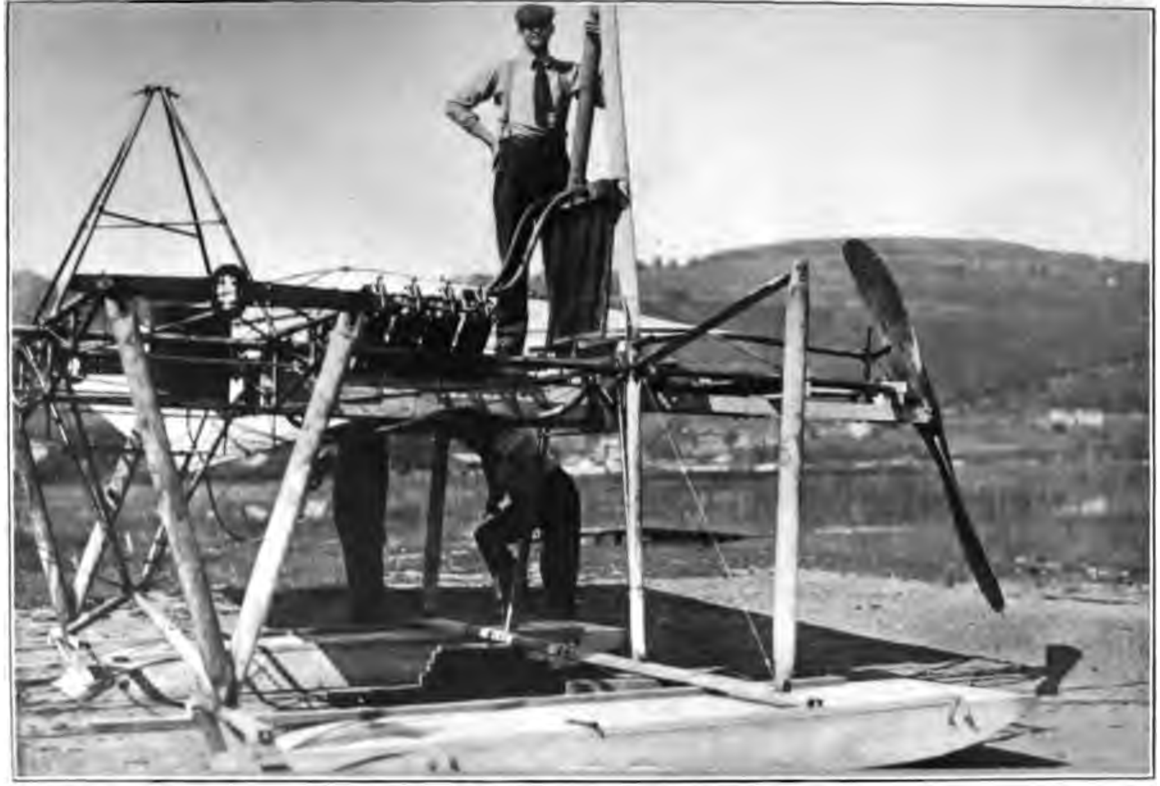
Langley Aeroplane (Built 1898-1903) Ready for Launching at Hammondsport, N. Y., May 28, 1914.



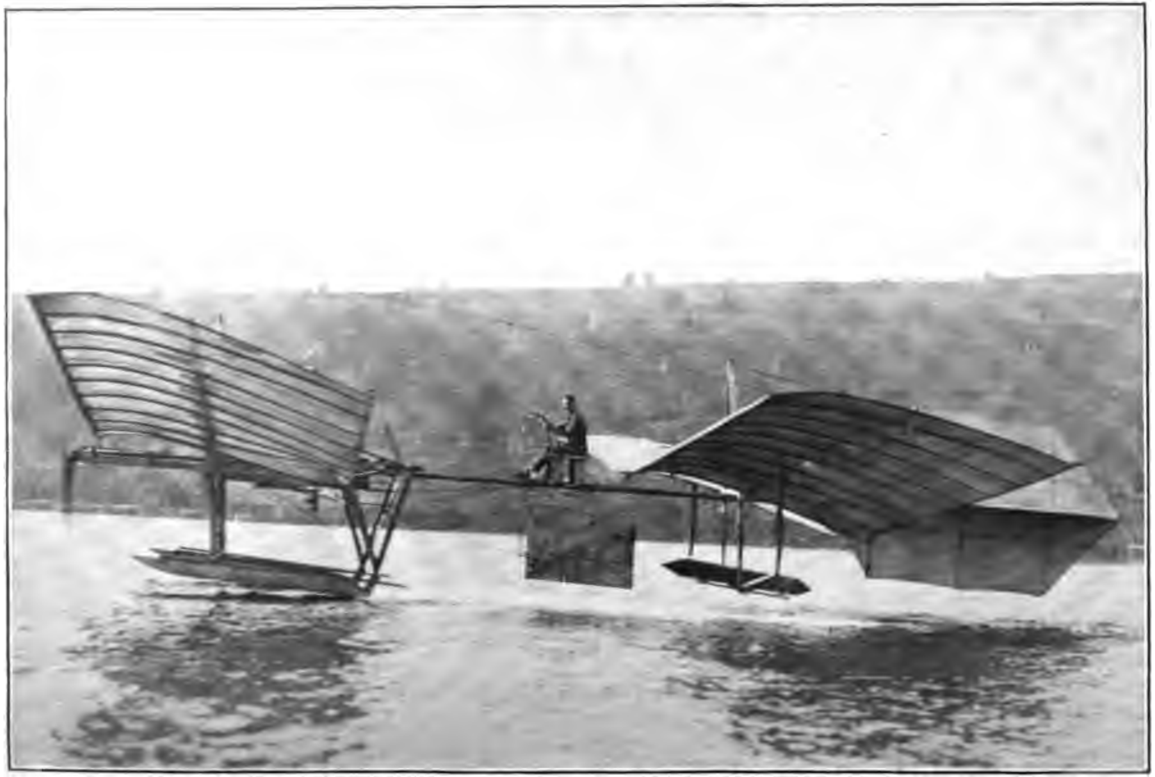
LANGLEY AEROPLANE JUST RISING FROM WATER, JUNE 2, 1914, PILOTED BY CURTISS.



FLIGHT OF LANGLEY AEROPLANE WITH ITS OWN POWER PLANT OVER LAKE KEUKA, JUNE 2, 1914, PILOTED BY CURTISS.



CURTISS 80-HORSEPOWER MOTOR AND TRACTOR SCREW MOUNTED ON LANGLEY AEROPLANE.



ELWOOD DOHERTY CLEARING THE WATER SEPTEMBER 17, 1914, IN THE LANGLEY AEROPLANE DRIVEN BY A CURTISS 80-HORSEPOWER MOTOR AND A TRACTOR SCREW.

its propellers whirring and its pilot supplementing, with manual control, if need be, the automatic stability of the machine. This method of launching, as shown by subsequent experimentalists, is a practical one and was favorably entertained by Mr. Curtiss. He also thought of starting from the ground with wheels, from the ice with skates, from the water with floats. Having at hand neither a first rate smooth field nor a sheet of ice, he chose to start from the water.

In the accompanying illustrations, plates 1 and 2 show the appearance of the Langley flying machine after Mr. Curtiss had provided it with hydroaeroplane floats and their connecting truss work. The steel main frame, the wings, the rudders, the engine and propellers all were substantially as they had been in 1903. The pilot had the same seat under the main frame, and the same general system of control as in 1903. He could raise or lower the craft by moving the big rear rudder up and down; he could steer right and left by turning the vertical rudder. He had no ailerons nor wing-warping mechanism, but for lateral balance depended upon the dihedral angle of the wings and upon suitable movements of his weight or of the vertical rudder. And here it may be noted that Langley had placed the vertical steering rudder under and to the rear of the center of gravity. So placed, it served as a fairly good aileron by exerting a turning movement about the longitudinal axis of the machine.

After the adjustments for actual flight had been made in the Curtiss factory, according to the minute descriptions contained in the Langley Memoir on Mechanical Flight, the aeroplane was taken to the shore of Lake Keuka, beside the Curtiss hangars, and assembled for launching. On a clear morning (May 28), and in a mild breeze, the craft was lifted onto the water by a dozen men and set going, with Mr. Curtiss at the steering wheel, ensconced in the little boat-shaped car under the forward part of the frame. Many eager witnesses and camera men were at hand, on shore and in boats. The four-winged craft, pointed somewhat across the wind, went skimming over the wavelets, then automatically headed into the wind, rose in level poise, soared gracefully for 150 feet, and landed softly on the water near the shore. Mr. Curtiss asserted that he could have flown farther, but, being unused to the machine, imagined the left wings had more resistance than the right. The truth is that the aeroplane was perfectly balanced in wing resistance, but turned on the water like a weather vane owing to the lateral pressure on its big rear rudder. Hence in future experiments this rudder was made turnable about a vertical axis, as well as about the horizontal axis used by Lan
Henceforth the little vertical rudder under the frame was kept
and inactive.

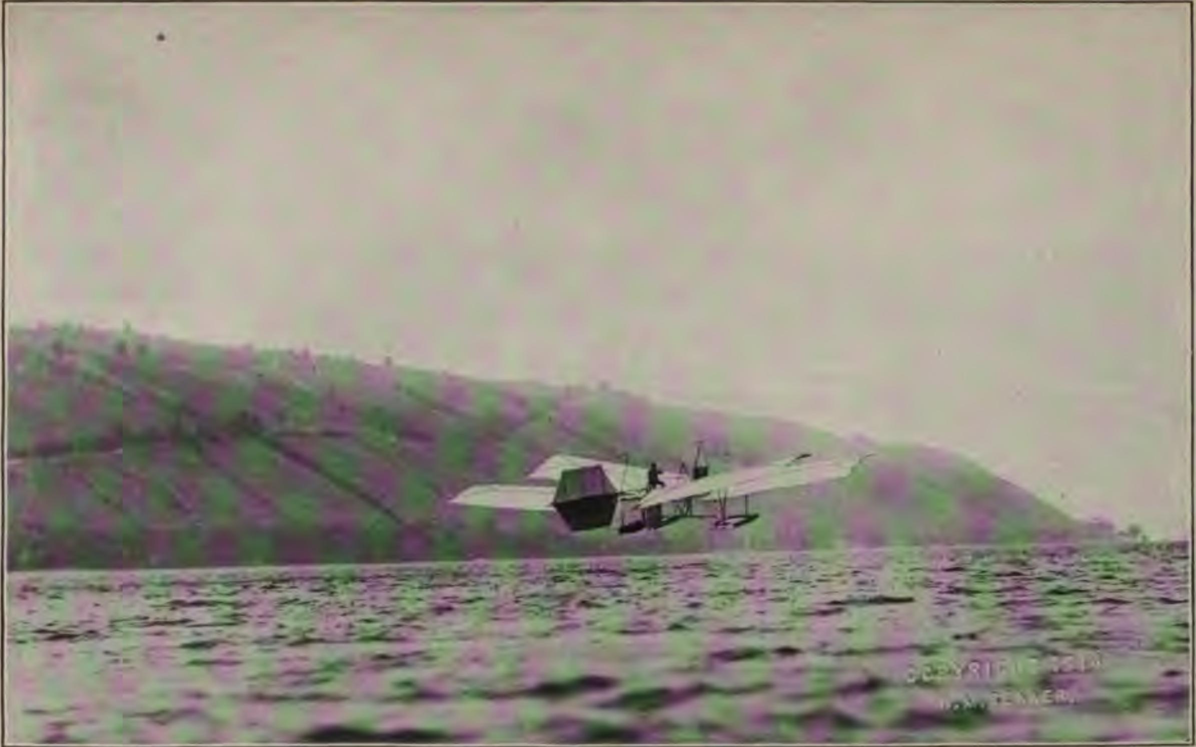
After a few more flights with the Langley aeroplane
as possible in its original condition, its engine and
were replaced by a Curtiss 80-horse motor and

tractor propeller mounted on the steel frame, well forward, as shown in the photographs. It was hoped in this way to spare the original engine and propeller bearings, which were none too strong for the unusual burden added by the floats. In 1903 the total weight of pilot and machine had been 830 pounds; with the floats lately added it was 1,170 pounds; with the Curtiss motor and all ready for flight it was 1,520 pounds. But notwithstanding these surplus additions of 40 per cent and 85 per cent above the original weight of the craft, the delicate wing spars and ribs were not broken, nor was any part of the machine excessively overstrained.

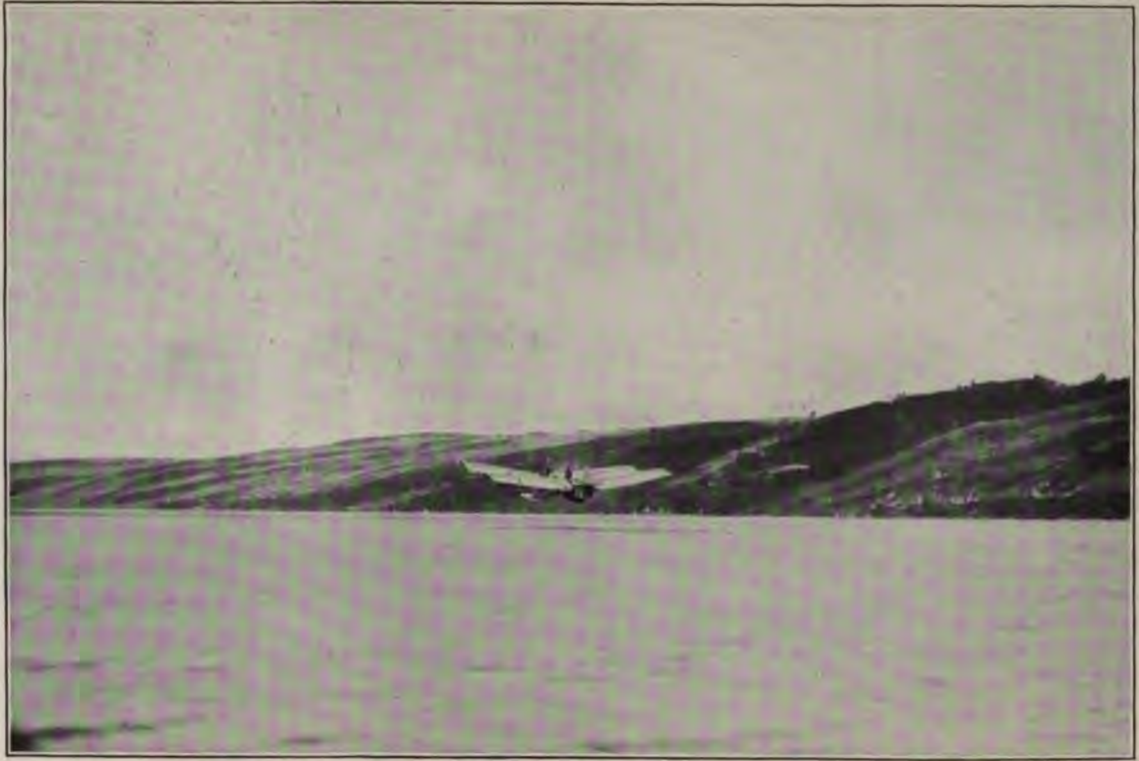
Owing to the pressure of other work at the factory, the aeroplane equipped with the Curtiss motor was not ready for further flights till September. In the absence of Mr. Curtiss, who had gone to California in August, a pupil of his aviation school, Mr. Elwood Doherty, volunteered to act as pilot.

During some trials for adjusting the aeroplane controls and the center of gravity, Mr. Doherty, on the afternoon of September 17, planed easily over the water, rose on level wing, and flew about 450 feet, at an elevation of 2 or 3 yards, as shown by the accompanying photographs of that date. Presently two other like flights were made. Mr. Doherty found that with the forewings at 10° incidence, the rear ones at 12°, and the pilot's seat on the main frame about midway between the wings, the flier responded nicely to the movements of the pilot wheel. A slight turn of the wheel steered the craft easily to right or left, a slight pull or push raised or lowered it. The big double tail, or rudder, which responded to these movements, was the only steering or control surface used. The breaking of the 8-foot tractor screw terminated these trials for the day. The waves indicate the strength of the wind during the flights.

On September 19, using a 9-foot screw, Mr. Doherty began to make longer flights. A pleasant off-shore breeze rippled the water, but without raising whitecaps. A dozen workmen, lifting the great tandem monoplane from the shore, with the pilot in his seat, waded into the lake and set it gently on the water. A crowd of witnesses near at hand, and many scattered about the shores, and on the lofty vine-clad hills, stood watching expectantly. When some of the official observers and photographers, in a motor boat, were well out in the lake, a man in high-top boots, standing in the water, started the propeller, and stepped quickly out of the way. Then with its great yellow wings beautifully arched and distended, the imposing craft ran swiftly out from the shore, gleaming brilliantly in the afternoon sun. At first the floats and lower edges of the rudders broke the water to a white surge, then as the speed increased they rose more and more from the surface. Presently the rear floats and the rudders *cleared* the water, the front floats still skipping on their heels, white

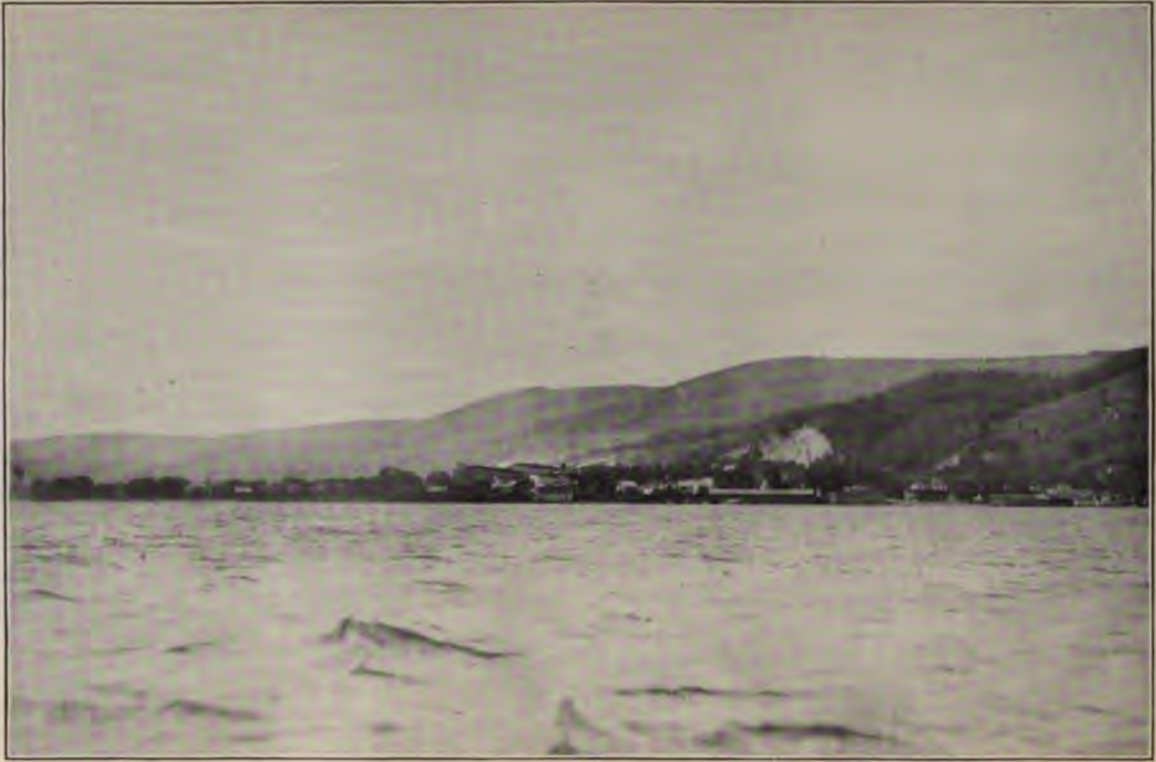


FLIGHT OF LANGLEY AEROPLANE ABOVE LAKE KEUKA SEPTEMBER 17, 1914, PILOTED BY E. DOHERTY AND DRIVEN BY A CURTISS MOTOR AND TRACTOR SCREW.



LANGLEY AEROPLANE IN FLIGHT SEPTEMBER 19, 1914; CLIMBING.

LANGLEY AEROPLANE IN FLIGHT OCTOBER 1, 1914; NATURAL POISE.



LANGLEY AEROPLANE IN FLIGHT OCTOBER 1, 1914. HAMMONDSPORT, N. Y., IN BACKGROUND.

with foam. The whole craft was now in soaring poise. It quickly approached the photographers, bearing on its back the alert pilot, who seemed to be scrutinizing every part of it and well satisfied to let it race. Then it rose majestically and sailed on even wing 1,000 feet; sank softly, skimmed the water, and soared another 1,000 feet; grazed the water again, rose and sailed 3,000 feet; turned on the water and came back in the same manner; and, as it passed the photographers, soared again nearly half a mile. The flights were repeated a few minutes later, then, owing to squally weather, were discontinued for 11 days.

On October 1, 1914, the aeroplane was launched at 11 a. m. in an off-shore breeze strong enough to raise whitecaps. Hovering within 30 feet of the water, and without material loss of speed, it made in quick succession flights of the following duration, as observed by four of us in a motor boat and timed by myself: 20 seconds, 20 seconds, 65 seconds, 20 seconds, 40 seconds, 45 seconds. As the speed through air averaged about 50 feet per second, the through air lengths of these flights were, respectively, 1,000 feet, 1,000 feet, 3,250 feet, 1,000 feet, 2,000 feet, 2,250 feet. As the aeroplane was now well out from shore among the heavy billows and white caps, Mr. Doherty landed it upon the water and turned it half about for the homeward flight. Thereupon the propeller tips struck the waves and were broken off, one casting a splinter through the center of the left wing. The pilot stopped the engine, rested in his seat, and was towed home by our motor boat. The flights were witnessed and have been attested by many competent observers.

As to the performance of the aeroplane during these trials, the pilot, Mr. E. Doherty, reports, and we observed, that the inherent lateral stability was excellent, the fore-and-aft control was satisfactory, and the movement of the craft both on the water and in the air was steady and suitable for practical flying in such weather. Apparently the machine could have flown much higher, and thus avoided touching the water during the lulls in the breeze; but higher flying did not seem advisable with the frail trussing of wings designed to carry 830 pounds instead of the 1,520 pounds actual weight.

At the present writing the Langley aeroplane is in perfect condition and ready for any further tests that may be deemed useful. But it has already fulfilled the purpose for which it was designed. It has demonstrated that, with its original structure and power, it is capable of flying with a pilot and several hundred pounds of useful load. It is the first aeroplane in the history of the world of which this can be truthfully said.

If the experiments be continued under more painstaking technical direction, longer flights can easily be accomplished. Mr. Manly, who designed the Langley engine and screws and who directed the construction and tests of the large aeroplane up to December 8, 1903, reports that he obtained from the propulsion plant a static thrust of 450 pounds, and that he once ran the engine under full load for 10 hours consecutively. This thrust is nearly 100 pounds more than that commonly obtained at Hammondsport with the same plant, and 20 pounds more than the static thrust obtained with the Curtiss motor on the day when it flew the aeroplane with 1,520 pounds aggregate weight. Hence, by restoring the engine and propellers to their original normal working condition they should be able to drive the aeroplane in successful flight with an aggregate weight of nearly 1,600 pounds, even when hampered with the floats and their sustaining truss work. With a thrust of 450 pounds, the Langley aeroplane, without floats, restored to its original condition and provided with stronger bearings, should be able to carry a man and sufficient supplies for a voyage lasting practically the whole day.

Dr. Langley's aerotechnic work may be briefly summarized as follows:

1. His aerodynamic experiments, some published and some as yet unpublished, were complete enough to form a basis for practical pioneer aviation.
2. He built and launched, in 1896, the first steam model aeroplane capable of prolonged free flight, and possessing good inherent stability.
3. He built the first internal-combustion motor suitable for a practical man-carrying aeroplane.
4. He developed and successfully launched the first gasoline model aeroplane capable of sustained free flight.
5. He developed and built the first man-carrying aeroplane capable of sustained free flight.

SOME ASPECTS OF INDUSTRIAL CHEMISTRY.[1]

By L. H. Baekeland, Sc. D.

While I appreciate deeply the distinction of speaking before you on the occasion of the fiftieth anniversary of the Columbia School of Mines, I realize, at the same time, that nobody here present could do better justice to the subject which has been chosen for this lecture, than the beloved master in whose honor the Charles Frederick Chandler lectureship has been created.

Dr. Chandler, in his long and eminently useful career as a professor and as a public servant, has assisted at the very beginning of some of the most interesting chapters of applied chemistry, here and abroad.

Some of his pupils have become leaders in chemical industry; others have found in his teachings the very conception of new chemical processes which made their names known throughout the whole world.

Industrial chemistry has been defined as "the chemistry of dollars and cents."

This rather cynical definition, in its narrower interpretation, seems to ignore entirely the far-reaching economic and civilizing influences which have been brought to life through the applications of science; it fails to do justice to the fact that the whole fabric of modern civilization becomes each day more and ever more interwoven with the endless ramifications of applied chemistry.

The earlier effects of this influence do not date back much beyond one hundred and odd years. They became distinctly evident during the first French Republic, increased under Napoleon, gradually spread to neighboring countries, and then reaching out farther, their influence is now obvious throughout the whole world.

France, during the revolution, scattered to the winds old traditions and conventionalities, in culture as well as in politics. Until then, she had mainly impressed the world by the barbaric, wasteful splendor of her opulent kings, at whose courts the devotees of science received scant attention in comparison to the more ornamental artists and belles-lettrists, who were petted and rewarded alongside of the all-important men of the sword.

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[1] An address given at Columbia University to inaugurate the Charles F. Chandler lectureship. Copyright, 1914, by the Columbia University Press. Reprinted by permission.

In fact, as far as the culture of science was concerned, the Netherlands, Germany, and Italy, and more particularly England, were head and shoulders above the France of "le Roi Soleil."

The struggle of the new régime put France in the awkward position of the legendary beaver which "had to climb a tree."

If for no other reason, she needed scientists to help her in her wars against the rulers of other European nations. She needed them just as much for repairing her crippled finances and her badly disturbed industries which were dependent upon natural products imported until then, but of which the supply had suddenly been cut off by the so-called continental blockade. Money prizes and other inducements had been offered for stimulating the development of chemical processes, and—what is more significant—patent laws were promulgated so as to foster invention.

Nicolas Leblanc's method for the manufacture of soda to replace the imported alkalis, Berthollet's method for bleaching with chlorine, the beet-sugar industry, to replace cane sugar imported from the colonies, and several other processes, were proposed.

All these chemical processes found themselves soon lifted from the hands of the secretive alchemist or the timid pharmacist to the rank of real manufacturing methods. Industrial chemistry had begun its lusty career.

First successes stimulated new endeavors, and small wonder is it that France, with these favorable conditions at hand, for a while at least, entered into the most glorious period of that part of her history which relates to the development of chemistry, and the arts dependent thereon.

It is difficult to imagine that at that time Germany, which now occupies such an enviable position in chemistry, was so far behind that even in 1822, when Liebig wanted to study chemistry at the best schools, he had to leave his own country and turn to Gay-Lussac, Thénard, and Dulong in Paris.

But the British were not slow to avail themselves of the new opportunities in chemical manufacturing so clearly indicated by the first successes of the French. Their linen bleacheries in Scotland and England soon used an improved method for bleaching with chloride of lime, developed by Tennant, which brought along the manufacture of other chemicals relating thereto, like sulphuric acid and soda.

The chemical reactions involved in all these processes are relatively simple, and after they were once well understood it required mainly resourceful engineering and good commercial abilities to build up successfully the industries based thereon.

From this epoch on dates the beginning of the development of that important industry of heavy chemicals in which the British led the world for almost a century.

In the same way, England had become the leader in another important branch of chemical industry—the manufacture of coal gas.

The Germans were soon to make up for lost time. Those same German universities which, when Liebig was a young man, were so poorly equipped for the study of chemistry, were now enthusiastically at work on research along the newer developments of the physical sciences, and before long the former pupils of France, in their turn, became teachers of the world.

Liebig had inaugurated for the chemical students working under him his system of research laboratories; however modest these laboratories may have been at that time, they carried bodily the study of chemistry from pedagogic boresomeness into a captivating cross-examination of nature.

And it seemed as if nature had been waiting impatiently to impart some of her secrets to the children of men, who for so many generations had tried to settle truth and knowledge by words and oratory and by brilliant displays of metaphysical controversies.

Indeed, at that time a few kitchen tables, some clumsy glassware, a charcoal furnace or two, some pots and pans, and a modest balance were all that was needed to make nature give her answers.

These modest paraphernalia, eloquent by their very simplicity, brought forth rapidly succeeding discoveries. One of them was truly sensational: Liebig and Wöhler succeeded in accomplishing the direct synthesis of urea; thinking men began to realize the far-reaching import of this revolutionary discovery whereby a purely organic substance had been created in the laboratory by starting exclusively from inorganic materials. This result upset all respected doctrines that organic substances are of a special enigmatic constitution, altogether different from inorganic or mineral compounds, and that they only could be built up by the agency of the so-called "vital force"—whatever that might mean.

Research in organic chemistry became more and more fascinating; all available organic substances were being investigated one after another by restless experimentalists.

Coal tar, heretofore a troublesome by-product of gas manufacture, notwithstanding its uninviting, ill-smelling, black, sticky appearance, did not escape the general inquisitive tendency; some of its constituents, like benzol or others, were isolated and studied.

Under the brilliant leadership of Kékulé, a successful attempt was made to correlate the rapidly increasing new experimental observations in organic chemistry into a new theory which would try to explain all the numerous facts; a theory which became the signpost to the roads of further achievements.

The discovery of quickly succeeding processes for making from coal-tar derivatives numerous artificial dyes, rivaling, if passing, the most brilliant colors of nature, made the group of bold investigators still bolder. Research in organic chemistry began to find rapid rewards; entirely new and successful industries based on purely scientific data were springing up in England and France, as well as in Germany.

Some wide-awake leaders of these new enterprises, more particularly in Germany, soon learned that they were never hampered by too much knowledge, but that, on the contrary, they were almost continuously handicapped in their impatient onward march by insufficient knowledge, or by misleading conceptions, if not by incorrect published facts.

This is precisely where the study of organic chemistry received its greatest stimulating influence and soon put Germany, in this branch of science, ahead of all other nations.

Money and effort had to be spent freely for further research. The best scholars in chemistry were called into action. Some men, who were preparing themselves to become professors, were induced to take a leading part as directors in one or another of the new chemical enterprises. Others, who refused to forsake their teachers' career, were retained as advisers or guides, and, in several instances, the honor of being the discoverers of new processes, or a new dye, was made more substantial by financial rewards. The modest German university professor, who heretofore had lived within a rather narrow academic sphere, went through a process of evolution, where the rapidly growing chemical industry made him realize his latent powers and greater importance, and broadened his influence far beyond the confines of his lecture room. Even if he were altrustic enough to remain indifferent to fame or money, he felt stimulated by the very thought that he was helping, in a direct manner, to build up the nation and the world through the immediate application of the principles of science.

In the beginning science did all the giving and chemical industry got most of the rewards; but soon the rôles began to change to the point where frequently they became entirely inverted. The universities did not furnish knowledge fast enough to keep pace with the requirements of the rapidly developing new industries. Modern research laboratories were organized by some large chemical factories on a scale never conceived before with a lavishness which made the best equipped university laboratory appear like a timid attempt. Germany, so long behind France and England, had become the recognized leader in organic manufacturing processes, and developed a new industrial chemistry based more on the thorough knowledge of organic chemistry than on engineering skill.

In this relation it is worth while to point out that the early organic industrial chemistry, through which Germany was soon to become so important, at first counted its output not in tons, but in pounds—not in size nor in quantity, but in variety and quality.

Now let us see how Germany won her spurs in chemical engineering as well.

At the beginning, the manufacturing problems in organic chemistry involved few if any serious engineering difficulties, but required most of all a sound theoretical knowledge of the subject; this put a premium on the scientist and could afford, for a while at least, to ignore the engineer. But when growing developments began to claim the help of good engineers there was no difficulty whatsoever in supplying them, nor in making them cooperate with the scientists. In fact, since then Germany has solved just as successfully some of the most extraordinary chemical engineering problems ever undertaken, although the development of such processes was entered upon at first from the purely scientific side.

In almost every case it was only after the underlying scientific facts had been well established that any attempt was made to develop them commercially.

Healthy commercial development of new scientific processes does not build its hope of success upon the cooperation of that class of "promoters" which are always eager to find any available pretext for making "quick money," and whose scientific ignorance contributes conveniently to their comfort by not interfering too much with their self-assurance and their voluble assertions. The history of most of the successful recent chemical processes abounds in examples where, even after the underlying principles were well established, long and costly preparatory team work had to be undertaken; where foremost scientists, as well as engineers of great ability, had to combine their knowledge, their skill, their perseverance, with the support of large chemical companies, who, in their turn, could rely on the financial backing of strong banking concerns, well advised by tried expert specialists.

History does not record how many processes thus submitted to careful study were rejected because, on close examination, they were found to possess some hopeless shortcomings. In this way numerous fruitless efforts and financial losses were averted, where less carefully accumulated knowledge might have induced less scrupulous promoters to secure money for plausible but ill-advised enterprises.

In the history of the manufacture of artificial dyes no chapter gives a more striking instance of long, assiduous, and expensive preliminary work of the highest order than the development of the industrial synthesis of indigo. Here was a substance of enormous consumption which, until then, had been obtained from the tropics as a natural product of agriculture.

Prof. von Baeyer and his pupils, by long and clever laboratory work, had succeeded in unraveling constitution of this indigo dye, and had finally indicated some possible methods of synthesis. Notwithstanding all this, it took the Badische Aniline & Soda Fabrik about 20 years of patient research work, carried out by a group of eminent chemists and engineers, before a satisfactory method was devised by which the artificial product could compete in price and in quality with natural indigo.

Germany, with her well-administered and easily enforcible patent laws, has added, through this very agency, a most vital inducement for pioneer work in chemical industries. Who otherwise would dare to take the risk of all the expenses connected with this class of creative work? Moreover, who would be induced to publish the result of his discoveries far and wide throughout the whole world in that steadily flowing stream of patent literature, which, much sooner than any textbooks or periodicals, enables one worker to be benefited and to be inspired by the publication of the latest work of others?

The development of some problems of industrial chemistry has enlisted the brilliant collaboration of men of so many different nationalities that the final success could not, with any measure of justice, be ascribed exclusively to one single race or nation; this is best illustrated by the invention of the different methods for the fixation of nitrogen from the air.

This extraordinary achievement, although scarcely a few years old, seems already an ordinary link in the chain of common, current events of our busy life; and yet, the facts connected with this recent conquest reveal a modern tale of great deeds of the race—an epos of applied science.

Its story began the day when chemistry taught us how indispensable are the nitrogeneous substances for the growth of all living beings.

Generally speaking, the most expensive foodstuffs are precisely those which contain most nitrogen; for the simple reason that there is, and always has been, at some time or another, a shortage of nitrogenous foods in the world. Agriculture furnishes us these proteid or nitrogen containing bodies, whether we eat them directly as vegetable products or indirectly as animals which have assimilated the proteids from plants. It so happens, however, that by our ill-balanced methods of agriculture we take nitrogen from the soil much faster than it is supplied to the soil through natural agencies. We have tried to remedy this discrepancy by enriching the soil with manure or other fertilizers, but this has been found totally insufficient, especially with our methods of intensive culture—our fields want more nitrogen. So agriculture has been looking anxiously around to find new sources of nitrogen fertilizer. For a short time an excellent supply was found in the guano deposits of Peru; but this material was used up so eagerly that the supply lasted only a very few years. In the meantime, the ammonium salts recovered from the by-products of the gas works have come into steady use as nitrogen fertilizer. But here again the supply is entirely insufficient, and during the later period our main reliance has been placed on the natural beds of sodium nitrate, which are found in the desert regions of Chile. This has been, of late, our principal source of nitrogen for agriculture, as well as for the many industries which require saltpeter or nitric acid.

In 1898 Sir William Crookes, in his memorable presidential address before the British Association for the Advancement of Science, called our attention to the threatening fact that, at the increasing rate of consumption, the nitrate beds of Chile would be exhausted before the middle of this century. Here was a warning—an alarm call—raised to the human race by one of the deepest scientific thinkers of our generation. It meant no more nor less than that before long our race would be confronted with nitrogen starvation. In a given country, all other conditions being equal, the abundance or the lack of nitrogen available for nutrition is a paramount factor in the degree of general welfare, or of physical decadence. The less nitrogen there is available as foodstuffs, the nearer the population is to starvation. The great famines in such nitrogen-deficient countries as India and China and Russia are sad examples of nitrogen starvation.

And yet, nitrogen, as such, is so abundant in nature that it constitutes four-fifths of the air we breathe. Every square mile of our atmosphere contains nitrogen enough to satisfy our total consumption for over half a century. However, this nitrogen is unavailable as long as we do not find means to make it enter into some suitable chemical combination. Moreover, nitrogen was generally considered inactive and inert, because it does not enter readily in chemical combination.

William Crookes's disquieting message of rapidly approaching nitrogen starvation did not cause much worry to politicians—they seldom look so far ahead into the future. But to the men of science it rang like a reproach to the human race. Here, then, we were in possession of an inexhaustible store of nitrogen in the air, and yet, unless we found some practical means for tying some of it into a suitable chemical combination we should soon be in a position similar to that of a shipwrecked sailor, drifting around on an immense ocean of brine, and yet slowly dying for lack of drinking water.

As a guiding beacon there was, however, that simple experiment, carried out in a little glass tube, as far back as 1875, by both Cavendish and Priestley, which showed that if electric sparks were passed through air the oxygen thereof was able to burn some of the nitrogen and to engender nitrous vapors.

This seemingly unimportant laboratory curiosity, so long dormant in the textbooks, was made a starting point by Charles S. Bradley and D. R. Lovejoy, in Niagara Falls, for creating the first industrial apparatus for converting the nitrogen of the air into nitric acid by means of the electric arc.

As early as 1902 they published their results as well as the details of their apparatus. Although they operated only one full-sized unit, they demonstrated conclusively that nitric acid could thus be produced from the air in unlimited quantities. We shall examine later the reasons why this pioneer enterprise did not prove a commercial success; but to these two American inventors belongs, undoubtedly, the credit of having furnished the first answer to the distress call of Sir William Crookes.

In the meantime many other investigators were at work at the same problem, and soon from Norway's abundant waterfalls came the news that Birkeland and Eyde had solved successfully, and on a commercial scale, the same problem by a differently constructed apparatus. The Germans, too, were working on the same subject, and we heard that Schoenherr, also Pauling, had evolved still other methods, all, however, based on the Cavendish-Priestley principle of oxidation of nitrogen. In Norway alone the artificial saltpeter factories use now, day and night, over 200,000 electrical horsepower, which will soon be doubled; while a further addition is contemplated which will bring the volume of electric current consumed to about 500,000 horsepower. The capital invested at present in these works amounts to $27,000,000.

Frank and Caro, in Germany, succeeded in creating another profitable industrial process whereby nitrogen could be fixed by carbide of calcium, which converts it into calcium cyanamide, an excellent fertilizer by itself. By the action of steam on cyanamide, ammonia is produced, or it can be made the starting point of the manufacture of cyanides, so profusely used for the treatment of gold and silver ores.

Although the synthetic nitrates have found a field of their own, their utilization for fertilizers is smaller than that of the cyanamide; and the latter industry represents to-day an investment of about $30,000,000, with 3 factories in Germany, 2 in Norway, 2 in Sweden, 1 in France, 1 in Switzerland, 2 in Italy, 1 in Austria, 1 in Japan, 1 in Canada, but not any in the United States. The total output of cyanamide is valued at $15,000,000 yearly and employs 200,000 horsepower, and preparations are made at almost every existing plant for further extensions. An English company is contemplating the application of 1,000,000 horsepower to the production of cyanamide and its derivatives, 600,000 of which have been secured in Norway and 400,000 in Iceland.

But still other processes are being developed, based on the fact that certain metals or metalloids can absorb nitrogen, and can thus be converted into nitrides; the latter can either be used directly as fertilizers or they can be made to produce ammonia under suitable treatment.

The most important of these nitride processes seems to be that of Serpek, who, in his experimental factory at Niedermorschweiler, succeeded in obtaining aluminum nitride in almost theoretical quantities, with the use of an amount of electrical energy eight times less than that needed for the Birkeland-Eyde process and one-half less than for the cyanamide process, the results being calculated for equal weights of "fixed" nitrogen.

A French company has taken up the commercial application of this process which can furnish, besides ammonia, pure alumina for the manufacture of aluminum metal.

An exceptionally ingenious process for the direct synthesis of ammonia by the direct union of hydrogen with nitrogen has been developed by Haber in conjunction with the chemists and engineers of the Badische Aniline & Soda Fabrik.

The process has the advantage that it is not, like the other nitrogen-fixation processes, paramountly dependent upon cheap power; for this reason, if for no other, it seems to be destined to a more ready application. The fact that the group of the three German chemical companies which control the process have sold out their former holdings in the Norwegian enterprises to a Norwegian-French group, and are now devoting their energies to the commercial installation of the Haber process, has quite some significance as to expectation for the future.

The question naturally arises: Will there be an overproduction and will these different rival processes not kill each other in slaughtering prices beyond remunerative production?

As to overproduction, we should bear in mind that nitrogen fertilizers are already used at the rate of about $200,000,000 worth a year, and that any decrease in price, and, more particularly, better education in farming, will probably lead to an enormously increased consumption. It is worth mentioning here that in 1825 the first shipload of Chile saltpeter which was sent to Europe could find no buyer and was finally thrown into the sea as useless material.

Then again, processes for nitric acid and processes for ammonia, instead of interfering, are supplementary to each other, because the world needs ammonia and ammonium salts, as well as nitric acid or nitrates.

It should be pointed out also that ultimately the production of ammonium nitrate may prove the most desirable method so as to minimize freight; for this salt contains much more nitrogen to the ton than is the case with the more bulky calcium salt, under which form synthetic nitrates are now put into the market.

Before leaving this subject, let us examine why Bradley and Lovejoy's efforts came to a standstill where others succeeded.

First of all, the cost of power at Niagara Falls is three to five times higher than in Norway, and although at the time this was not strictly prohibitive for the manufacture of nitric acid, it was entirely beyond hope for the production of fertilizers. The relatively high cost of power in our country is the reason why the cyanamide enterprise had to locate on the Canadian side of Niagara Falls, and why, up till now, outside of an experimental plant in the South (a 4,000 horsepower installation in North Carolina, using the Pauling process), the whole United States has not a single synthetic nitrogen fertilizer works.

The yields of the Bradley-Lovejoy apparatus were rather good. They succeeded in converting as much as 2½ per cent of the air, which is somewhat better than their successors are able to accomplish.

But their units, 12 kilowatts, were very much smaller than the 1,000 to 3,000 kilowatts now used in Norway; they were also more delicate to handle, all of which made installation and operation considerably more expensive.

However, this was the natural phase through which any pioneer industrial development has to go, and it is more than probable that in the natural order of events these imperfections would have been eliminated.

But the killing stroke came when financial support was suddenly withdrawn.

In the successful solution of similar industrial problems the originators in Europe were not only backed by scientifically well-advised bankers, but they were helped to the rapid solution of all the side problems by a group of specially selected scientific collaborators, as well as by all the resourcefulness of well-established chemical enterprises.

That such conditions are possible in the United States has been demonstrated by the splendid team work which led to the development of the modern tungsten lamp in the research laboratories of the General Electric Co., and to the development of the Tesla polyphase motor by the group of engineers of the Westinghouse Co.

True, there are endless subjects of research and development which can be brought to success by the efforts of single independent inventors, but there are some problems of applied science which are so vast, so much surrounded with ramifying difficulties, that no one man, nor two men, however exceptional, can either furnish the brains or the money necessary for leading to success within a reasonable time. For such special problems the rapid cooperation of numerous experts and the financial resources of large establishments are indispensable.

All these examples of the struggle for efficiency and improvement demonstrate why, in industrial chemistry, the question of dollars and cents has to be taken very much into consideration.

From this standpoint, at least, the "dollars and cents" argument can be interpreted as a symptom of industrial efficiency, and thus the definition sounds no longer as a reproach. With some allowable degree of accuracy, it formulates one of the economic aspects of any acceptable industrial chemical process.

Indeed, barring special conditions—as, for instance, incompetent or reckless management, unfair competition, monopolies, or other artificial privileges—the money success of a chemical process is the cash plebiscite of approval of the consumers. It is bound, after a time at least, to weed out the inefficient methods.

Some chemists who have little or no experience with industrial enterprises, are too much overinclined to judge a chemical process exclusively from the standpoint of the chemical reactions involved therein, without sufficient regard to engineering difficulties, financial requirements, labor problems, market and trade conditions, rapid development of the art involving frequent disturbing improvements in methods and expensive changes in equipment, advantages or disadvantages of the location of the plant, and other conditions so numerous and variable that many of them can hardly be foreseen even by men of experience.

And yet these seemingly secondary considerations most of the time become the deciding factor of success or failure of an otherwise well-conceived chemical process.

The cost of transportation alone frequently will decide whether a certain chemical process is economically possible or not. For instance, the big Washoe Smelter, in Montana, wastes enough sulphur dioxide gas to make daily 1,800 tons of sulphuric acid, but that smelter is too far distant from any possible market for such a quantity of otherwise valuable material.

Another example of the kind is found in the natural deposits of soda or soda lakes in California. One of these soda lakes contains from 30,000,000 to 42,000,000 tons of soda. Here is a natural source of supply which would be ample to satisfy the world's demand for many years to come. Similar deposits exist in other parts of the world, but the cost of transportation to a sufficiently large and profitable market is so exorbitant that, in the meantime, it is cheaper to erect at more convenient points expensive chemical works in which soda is made chemically and from where the market can be supplied more profitably.

In addition, we can cite the artificial nitrate processes in Norway, which, notwithstanding their low efficiency and expensive installation, can furnish nitrate in competition with the natural nitrate beds of Chile, because the latter are hampered by the cost of extraction from the soil where fuel for crystallization is expensive, in addition to the considerable cost of freight.

But there is no better example illustrating the far-reaching effect of seemingly secondary conditions upon the success of a chemical process than the history of the Leblanc soda process.

This famous process was the forerunner of chemical industry. For almost a century it dominated the enormous group of industries of heavy chemicals, so expressively called by the French "La Grande Industrie Chimique," and now we are witnesses of the lingering death agonies of this chemical colossus. Through the Leblanc process large fortunes have been made and lost; but even after its death it will leave a treasure of information to science and chemical engineering the value of which can hardly be overestimated.

Here then is a very well worked-out process, admirably studied in all its details, which in its heroic struggle for existence has drawn upon every conceivable resource of ingenuity furnished by the most learned chemists and the most skillful engineers, who succeeded in bringing it to an extraordinary degree of perfection, and which, nevertheless, has to succumb before inexorable although seemingly secondary conditions.

Strange to say its competitor the Solvay process, entered into the arena after a succession of failures. When Solvay, as a young man, took up this process, he was himself totally ignorant of the fact that no less than about a dozen able chemists had invented and reinvented the very reaction on which he had pinned his faith; that, furthermore, some had tried it on a commercial scale, and had in every instance encountered failure. At that time all this must undoubtedly have been to young Solvay a revelation sufficient to dishearten almost anybody. But he had one predominant thought to which he clung as a last hope of success, and which would probably have escaped most chemists; he reasoned that in this process he starts from two watery solutions which, when brought together, precipitate a dry product, bicarbonate of soda; in the Leblanc process the raw materials must be melted together with the use of expensive fuel, after which the mass is dissolved in water, losing all these valuable heat units, while more heat has again to be applied to evaporate to dryness.

After all, most of the weakness of the Leblanc process resides in the greater consumption of fuel. But the cost of fuel, here again, is determined by freight rates. This is so true that we find that the last few Leblanc works which manage to keep alive are exactly those which are situated near unusually favorable shipping points, where they can obtain cheap fuel, as well as cheap raw materials, and whence they can most advantageously reach certain profitable markets.

But another tremendous handicap of the Leblanc process is that *it gives* as one of its by-products hydrochloric acid. Profitable use for this acid, as such, can be found only to a limited extent. It is true that hydrochloric acid could be used in much larger quantities for many purposes where sulphuric acid is now used, but it has, against sulphuric acid, a great freight disadvantage. In its commercially available condition it is an aqueous solution, containing only about one-third of real acid, so that the transportation of 1 ton of acid practically involves the extra cost of freight of about 2 tons of water. Furthermore, the transportation of hydrochloric acid in anything but glass carboys involves very difficult problems in itself, so that the market for hydrochloric acid remains always within a relatively small zone from its point of production. However, for a while at least, an outlet for this hydrochloric acid was found by converting it into a dry material which can easily be transported, namely, chloride of lime or bleaching powder.

The amount of bleaching powder consumed in the world practically dictated the limited extent to which the Leblanc process could be profitably worked in competition with the Solvay process. But even this outlet has been blocked during these later years by the advent of the electrolytic alkali processes, which have sprung up successfully in several countries, and which give as a cheap by-product chlorine, which is directly converted into chloride of lime.

To-day any process which involves the production of large quantities of hydrochloric acid, beyond what the market can absorb as such, or as derivatives thereof, becomes a positive detriment, and foretells failure of the process. Even if we could afford to lose all the acid, the disposal of large quantities thereof conflicts immediately with laws and ordinances relative to the pollution of the atmosphere or streams, or the rights of neighbors, and occasions expensive damage suits.

Whatever is said about hydrochloric acid applies to some extent to chlorine, produced in the electrolytic manufacture of caustic soda. Here again the development of the latter industry is limited, primarily by the amount of chlorine which the market, as such, or as chlorinated products, can absorb.

At any rate, chlorine can be produced so much cheaper by electrolytic caustic alkali processes than formerly, and in the meantime the market price of chloride of lime has already been cut about in half.

In as far as the rather young electrolytic alkali industry has taken a considerable development in the United States, let us examine it somewhat nearer.

At present, the world's production of chloride of lime approximates about half a million tons.

We used to import all our chloride of lime from Europe until about 15 years ago, when the first successful electrolytic alkali works were started at Niagara Falls. That ingenious mercury cell of Hamilton Y. Castner—a pupil of Prof. Chandler and one of the illustrious sons of the Columbia School of Mines—was first used, and his process still furnishes a large part of all the electrolytic caustic soda and chlorine manufactured here and abroad.

At present about 30,000 electrical horsepower are employed uninterruptedly for the different processes used in the United States, and our home production has increased to the point where, instead of importing chloride of lime, we shall soon be compelled to export our surplus production.

It looks now as if, for the moment at least, any sudden considerable increase in the production of chloride of lime would lead to overproduction until new channels of consumption of chloride of lime or other chlorine products can be found.

However, new uses for chlorine are being found every day. The very fact that commercial hydrochloric acid of exceptional purity is now being manufactured in Niagara Falls by starting from chlorine indicates clearly that conditions are being reversed; no longer than a few years ago, when chlorine was manufactured exclusively by means of hydrochloric acid, this would have sounded like a paradox.

The consumption of chlorine for the preparation of organic chlorination products utilized in the dye-stuff industry is also increasing continually, and its use for the manufacture of tetrachloride of carbon and so-called acetylen chlorination products, has reached quite some importance.

There is probably a much overlooked but wider opening for chlorinated solvents in the fact that ethylen gas can be prepared now at considerably lower cost than acetylen, and that ethylen chloride, or the old known "Dutch Liquid," is an unusually good solvent. It has, furthermore, the great advantage that its specific gravity is not too high, and its boiling point, too, is about the right temperature. It ought to be possible to make it at such a low price that it would find endless applications where the use of other chlorination solvents has thus far been impossible.

The chlorination of ores for certain metallurgical processes may eventually open a still larger field of consumption for chlorine.

In the meantime liquefied chlorine gas, obtained by great compression, or by intense refrigeration, has become an important article of commerce, which can be transported in strong steel cylinders. Its main utilization resides in the manufacture of tin chloride by the Goldschmidt process for reclaiming tin scrap. It is finding also increased applications as a bleaching agent and for the purification of drinking water, as well as for the manufacture of various chlorination products.

Its great handicap for rapid introduction is again the question of freight, where heavy and expensive containers become indispensable.

In most cases the transportation problem of chlorine is solved more economically by handling it as chloride of lime, which, after all, represents chlorine or oxygen in solid form, easily transportable.

It would seem as if the freight difficulty could easily be eliminated by producing the chlorine right at the spot of consumption. But this is not always so simple as it may appear. To begin with, the cost of an efficient plant for any electrolytic operation is always unusually high as compared to other chemical equipments. Then, also, small electrolytic alkali plants are not profitable to operate. Furthermore, the conditions for producing cheap chlorine depend on many different factors, which all have to coordinate advantageously; for instance, cheap power, cheap fuel, and cheap raw materials are essential, while, at the same time, a profitable outlet must be found for the caustic soda.

Lately there has been a considerable reduction of the market price of caustic soda; all this may have for effect that the less efficient electrolytic processes will gradually be eliminated, although this may not necessarily be the case for smaller plants which do not compete in the open market, but consume their own output for some special purpose.

Several distinct types of electrolytic cells are now in successful use, but experience seems to demonstrate that the so-called diaphragm cells are cheapest to construct and to operate, provided, however, no exception be taken to the fact that the caustic soda obtained from diaphragm cells always contains some sodium chloride, usually varying from 2 to 3 per cent, which it is not practical to eliminate, but which for almost all purposes does not interfere in the least with its commercial use.

Mercury cells give a much purer caustic soda, and this may, in some cases, compensate for their more expensive equipment and operation. Moreover, there are some purposes where the initial caustic solution of rather high concentration, produced directly in these cells, can be used as it is without further treatment, thus obviating further concentration and cost of fuel.

The expenses for evaporation and elimination of salt from the raw caustic solutions increase to an exaggerated extent with some types of diaphragm cells, which produce only very weak caustic liquors. This is also the case with the so-called "gravity cell," sometimes called the "bell type," or "Aussig type," of cell. But these gravity cells have the merit of dispensing with the delicate and expensive problem of diaphragms. On the other hand, their units are very small, and on this account they necessitate a rather complicated installation, occupying an unusually large floor space and expensive buildings.

The general tendency is now toward cells which can be used in very large units, which can be housed economically, and of which the general cost of maintenance and renewal is small; some of the modern types of diaphragm cells are now successfully operating with 3,000 to 5,000 amperes per cell.

As to the possible future improvements in electrolytic alkali cells, we should mention that in some types the current efficiencies have practically reached their maximum, and average ampere efficiencies as high as 95 to 97 per cent have been obtained in continuous practice. The main difficulty is to reinforce these favorable results by the use of lower voltage without making the units unnecessarily bulky or expensive in construction or in maintenance, all factors which soon outweigh any intended saving of electric current.

Here, more than in any other branch of chemical engineering, it is easy enough to determine how "good" a cell is on a limited trial, but it takes expensive, long-continuous use on a full commercial scale, running uninterruptedly day and night for years, to find out how "bad" it is for real commercial practice.

In relation to the electrolytic alkali industry a great mistake is frequently committed by considering the question of power as paramount; true enough, cheap power is very important, almost essential, but certainly it is not everything. There have been cases where it was found much cheaper in the end to pay almost double for electric current in a certain locality than in another site not far distant from the first, for the simple reason that the cheaper power supply was hampered by frequent interruptions and expensive disturbances, which more than offset any possible saving in cost of power.

In further corroboration, it is well known that some of the most successful electrolytic soda manufacturers have found it to their advantage to sacrifice power by running their cells at decidedly higher voltage than is strictly necessary—which simply means consuming more power—and this in order to be able to use higher current densities, thereby increasing considerably the output of the same size units, and thus economizing on the general cost of plant operation. Here is one of the ever-recurring instances in chemical manufacturing where it becomes more advantageous to sacrifice apparent theoretical efficiency in favor of industrial expediency.

All this does not diminish the fact that the larger electrochemical industries can only thrive where cheap power is available.

Modern progress of electrical engineering has given us the means to utilize so-called natural powers; until now, however, we have only availed ourselves of the water power developed from rivers, lakes, and waterfalls. As far as large electric power generation is concerned, the use of the wind, or the tide, or the heat of the sun, represents, up till now, nothing much beyond a mere hope of future possibilities.

In the meantime it so happens, unfortunately, that many of the most abundant water powers of the world are situated in places of difficult access, far removed from the zone of possible utilization.

But, precisely on this account, it would appear, at first sight, as if the United States, with some of her big water powers situated nearer to active centers of consumption, would be in an exceptionally favorable condition for the development of electrochemical industries. On closer examination we find, however, that the cost of water power, as sold to manufacturers, is in general much higher than might be expected; at any rate, it is considerably more expensive than the cost of electric power utilized in the Norway nitrate enterprises.

This is principally due to the fact that in the United States water power, before it is utilized by the electrolytic manufacturer, has already to pay one, two, and sometimes three profits to as many intermediate interests, which act as so many middlemen between the original water power and the consumer. Only in such instances as in Norway, where the electrochemical enterprise and the development of the water power are practically in the same hands, can electric current be calculated at its real cheapest cost.

Neither should the fact be overlooked that the best of our water powers in the East are situated rather far inland. Although this does not matter much for the home market, it puts us at a decided disadvantage for the exportation of manufactured goods, in comparison again with Norway, where the electrolytic plants are situated quite close to a good sea harbor open in all seasons.

Some electrochemical enterprises require cheap fuel just as much as cheap power, and on this account it has proved sometimes more advantageous to dispense entirely with water power by generating gas for fuel as well as for power from cheap coal or still cheaper peat.

At present most of our ways of using coal are still cumbersome and wasteful, although several efficient methods have been developed which some day will probably be used almost exclusively, princiaplly in such places where lower grades of cheap coal are obtainable.

I refer here particularly to the valuable pioneer work of that great industrial chemist, Mond, on cheap water-gas production, by the use of a limited amount of air in conjunction with water vapor.

More recently this process has been extended by Caro, Frank, and others to the direct conversion of undried peat into fuel gas.

By the use of these processes peat or lower grades of coal, totally unsuitable for other purposes, containing, in some instances, as much as 60 to 70 per cent of incombustible constituents, can be used to good advantage in the production of fuel for power generation.

Whether Mond gas will ever be found advantageous for distribution to long distances is questionable, because its heating value per cubic foot is rather less than that of ordinary water gas, but this does not interfere with its efficient use in internal-combustion engines.

In general, our methods for producing or utilizing gas in our cities do scant justice to the extended opportunities indicated by our newer knowledge.

Good fuel gas could be manufactured and distributed to the individual household consumer at considerably cheaper rates, if it were not for antiquated municipal specifications, which keep on prescribing photometric tests instead of insisting on standards of fuel value, which makes the cost of production unnecessarily high, and disregards the fact that for lighting the Welsbach mantle has rendered obsolete the use of highly carbureted gas as a bare flame. But for those unfortunate specifications, cheap fuel gas might be produced at some advantageous central point, where very cheap coal is available; such heating gas could be distributed to every house and every factory where it could be used cleanly and advantageously like natural gas, doing away at once with the black coal smoke nuisance, which now practically compels a city like New York to use nothing but the more expensive grades of anthracite coal. It would eliminate at the same time all the bother and expense caused through the clumsy and expensive methods of transportation and handling of coal and ashes; it would relieve us from many unnecessary middlemen which now exist between coal and its final consumer.

The newer large-sized internal-combustion engines are introducing increasing opportunities for new centers of power production where waste gas of blast-furnaces or coke-ovens, or where deposits of inferior coal or peat are available.

If such centers are situated near tide water this may render them still more advantageous for some electrochemical industries, which, until now, were compelled to locate near some inland water powers.

Nor should we overlook the fact that the newer methods for the production of cheap fuel gas offer excellent opportunities for an increased production of valuable tar by-products, and more particularly of ammonium salts; the latter would help to a not inconsiderable extent in furnishing more nitrogen fertilizer.

It is somewhat remarkable that a greater effort has already been made to start the industrial synthesis of nitrogen products than to economize all these hitherto wasted sources of ammonia.

In fact, science indicates still other ways, somewhat of a more radical nature, for correcting the nitrogen deficiencies in relation to our food supply.

Indeed, if we will look at this matter from a much broader standpoint we may find that, after all, the shortage of nitrogen in the world is attributable to a large extent to our rather one-sided system of agriculture. We do not sufficiently take advantage of the fact that certain plants, for instance those of the group of Leguminosæ, have the valuable property of easily assimilating nitrogen from the air, without the necessity of nitrogen fertilizers. In this way the culture of certain Leguminosæ can insure enough nitrogen for the soil, so that, in rotation with nitrogen-consuming crops, like wheat, we could dispense with the necessity of supplying any artificial nitrogen fertilizers.

The present nitrogen deficiency is influenced further by two other causes:

The first cause is our unnecessary exaggerated meat diet, in which we try to find our proteid requirements, and which compels us to raise so many cattle, while the amount of land which feeds one head of cattle could furnish, if properly cultivated, abundant vegetable food for a family of five.

The second cause is our insufficient knowledge of the way to grow and prepare for human food just those vegetables which are richest in proteids. Unfortunately, it so happens that exactly such plants as, for instance, the soy bean are not by any means easily rendered palatable and digestible; while any savage can eat raw meat, or can readily cook, boil, or roast it for consumption.

On this subject we can learn much from some Eastern people, like the Japanese, who have become experts in the art of preparing a variety of agreeable food products from that refractory soy bean, which contains such an astonishingly large amount of nutritious proteids, and which, long ago, became for Japan a wholesome, staple article of diet.

But on this subject the Western races have not yet progressed much beyond the point of preparing cattle feed and paint oil from the soy bean, although the more extended culture of this or similar plants might work about a revolution in our agricultural economics.

Agriculture, after all, is nothing but a very important branch of industrial chemistry, although most people seem to ignore the fact that the whole prosperity of agriculture is based on the success of that photochemical reaction which, under the influence of the light of the sun, causes the carbon dioxide of the air to be assimilated by the chlorophyl of the plant.

It is not impossible that photochemistry, which hitherto has busied itself almost exclusively within the narrow limits of the art of making photographic images, will some day attain a development of usefulness at least as important as all other branches of physical chemistry. In this broader sense photochemistry seems an inviting subject for the agricultural chemist. The possible rewards in store in this almost virgin field may in their turn by that effect of superinduction between industry and science, bring about a rapid development similar to what we have witnessed in the advancement of electricity, as well as chemistry, which both began to progress by bounds and leaps, way ahead of other sciences, as soon as their growing industrial applications put a high premium on further research.

Photochemistry may allow us some day to obtain chemical effects hitherto undreamed of. In general the action of light in chemical reactions seems incomparably less brutal than all means used heretofore in chemistry. This is the probable secret of the subtle chemical syntheses which happen in plant life. To try to duplicate these delicate reactions of nature by our present methods of high temperatures, electrolysis, strong chemicals, and other similar torture processes, seems like trying to imitate a masterpiece of Gounod by exploding a dynamite cartridge between the strings of a piano.

But there are endless other directions for scientific research relating to industrial applications which until now do not seem to have received sufficient attention.

For instance, from a chemical standpoint, the richest chemical enterprise of the United States, the petroleum industry, has hitherto chiefly busied itself with a rather primitive treatment of this valuable raw material, and little or no attention has been paid to any methods for transforming at least a part of these hydrocarbons into more ennobled products of commerce than mere fuel or illuminants.

A hint as to the enormous possibilities which may be in store in that direction is suggested by the recent work in Germany and England on synthetic rubber; the only factor which prevents extending the laboratory synthesis of rubber into an immense industrial undertaking is that we have not yet learned how to make cheaply the isoprene or other similar nonsaturated hydrocarbons which are the starting point in the process which changes their molecules by polymerization into rubber.

Nor has our science begun to find the best uses for such inexpensive and never exhaustible vegetable products as cellulose or starch. Quite true, several important manufactures, like that of paper, nitrocellulose, glucose, alcohol, vinegar, and some others, have been built on it; but to the chemist at least it seems as if a much greater development is possible in the cheaper and more extended production of artificial fiber. Although we have succeeded in making so-called artificial silk, this article is still very expensive; furthermore we have not yet produced a cheap, good, artificial fiber of the quality of wool.

If we have made ourselves independent of Chile for our nitrogen *supply,* we are still absolutely at the mercy of the Stassfurt mines in

Germany for our requirements of soluble potash salts, which are just as necessary for agriculture. Shall we succeed in utilizing some of the proposed methods for converting that abundant supply of feldspar, or other insoluble potash-bearing rocks, into soluble potash salts by combining the expensive heat treatment with the production of another material, like cement, which would render the cost of fuel less exorbitant? Or shall the problem be solved in setting free soluble potassium salts as a by-product in a reaction engendering other staple products consumed in large quantities?

We have several astonishingly conflicting theories about the constitution of the center of the globe, but we have not yet developed the means to penetrate the world's crust beyond some deep mines—merely an imperceptible faint scratch on the surface—and in the meantime we keep on guessing, while to-day astronomers know already more about the surface of the planet Mars than we know about the interior of the globe on which we live.

Nor have we learned to develop or utilize the tremendous pressures under which most minerals have been formed, and still less do we possess the means to try these pressures, in conjunction with intensely high temperatures.

No end of work is in store for the research chemist, as well as for the chemical engineer, who can think by himself, without always following the beaten track. We are only at the beginning of our successes; and yet, when we stop to look back to see what has been accomplished during the last generations, that big jump from the rule of thumb to applied science is nothing short of marvelous.

Whoever is acquainted with the condition of human thought to-day must find it strange, after all, that scarcely 70 years ago Mayer met with derision even among the scientists of the time when he announced to the world that simple but fundamental principle of the conservation of energy.

We can hardly conceive that just about the time the Columbia School of Mines was founded Liebig was still ridiculing Pasteur's ideas on the intervention of microorganisms in fermentation, which have proved so fecund in the most epoch-making applications in science, medicine, surgery, and sanitation, as well as in many industries.

Fortunately, true science, contrary to other human avocations, recognizes nobody as an "authority," and is willing to change her beliefs as often as better studied facts warrant it. This difference has been the most vital cause of her never ceasing progress.

To the younger generation, surrounded with research laboratories everywhere, it may cause astonishment to learn that scarcely 50 years ago that great benefactor of humanity, Pasteur, was still repeating his pathetic pleadings with the French Government to give him more suitable quarters than a damp, poorly lighted basement, in which he was compelled to carry on his research; and this was then the condition of affairs of no less a place than Paris, the same Paris that was spending, just at that time, endless millions for the building of her new Opera Palace.

Such facts should not be overlooked by those who might think that America has been too slow in fostering chemical research.

If the United States has not participated as early as some European countries in the development of industrial chemistry, this was chiefly because conditions here were so totally different from those of nations like Germany, England, and France that they did not warrant any such premature efforts.

In a country so full of primary resources, agriculture, forests, mines, and the more elementary industries directly connected therewith, as well as the problems of transportation, appealed more urgently to American intellectual men of enterprise.

Why should anybody here have tried to introduce new, difficult, or risky chemical industries when on every side more urgently important fields of enterprise were inviting all men of initiative?

Chemical industries develop along the lines furnished by the most immediate needs of a country. Our sulphuric acid industry, which can boast to-day of a yearly production of about 3,000,000 tons, had to begin in an exceedingly humble way, and the first small amounts of sulphuric acid manufactured here found a very scant outlet.

It required the growth of such fields of application as petroleum refining, superphosphates, explosives, and others, before the sulphuric acid industry could grow to what it is to-day.

At present, similar influences are still dominating our chemical industries; they are generally directed to the mass production of partly manufactured articles. This allows us to export, at present, to Germany, chemicals in crude form, but in greater value than the total sum of all the chemical products we are importing from her; although it can not be denied that a considerable part of our imports are products like alizarine, indigo, aniline dyes, and similar synthetic products which require higher chemical manufacturing skill.

In this connection it may be pointed out that our exports of oleomargarine to Germany alone are about equivalent to our imports of aniline dyes.

But all this does not alter the fact that in several important chemical industries the United States has been a pioneer. Such flourishing enterprises as that of the artificial abrasives, carborundum and alundum, calcium carbide, aluminum, and many others, testify how soon we have learned to avail ourselves of some of our water power.

One of the most important chemical industries of the world, the *sulphite cellulose* industry, of which the total annual production amounts to 3,500,000 tons, was originated and developed by a chemist in Philadelphia, B. C. Tilgman. But its further development was stopped for a while on account of the same old trouble, lack of funds, after $40,000 were spent, until some years later it was taken up again in Europe and reintroduced in the United States, where it has developed to an annual production of over 1,000,000 tons.

What has been accomplished in America in chemical enterprises, and what is going on now in industrial research, has been brilliantly set forth by Mr. Arthur D. Little.[1]

Nor at any time in the history of the United States was chemistry neglected in this country; this has recently been brought to light in the most convincing manner by Prof. Edgar F. Smith, of Philadelphia.[2]

The altruistic fervor of that little group of earlier American chemists who, in 1792, founded the Chemical Society of Philadelphia (probably the very first chemical society in the world), and in 1811 the Columbia Chemical Society of Philadelphia, is best illustrated by an extract of one of the addresses read at their meeting in 1798:

> The only true basis on which the independence of our country can rest are agriculture and manufactures. To the promotion of these nothing tends in a higher degree than chemistry. It is this science which teaches man how to correct the bad qualities of the land he cultivates by a proper application of the various species of manure, and it is by means of a knowledge of this science that he is enabled to pursue the metals through the various forms they put on in the earth, separate them from substances which render them useless, and at length manufacture them into the various forms for use and ornament in which we see them. If such are the effects of chemistry, how much should the wish for its promotion be excited in the breast of every American! It is to a general diffusion of knowledge of this science, next to the virtue of our countrymen, that we are to look for the firm establishment of our independence. And may your endeavors, gentlemen, in this cause, entitle you to the gratitude of your fellow citizens.

This early scientific spirit has been kept alive throughout the following century by such American chemists as Robert Hare, E. N. Horsford, Wolcott Gibbs, Sterry Hunt, Lawrence Smith, Carey Lea, Josiah P. Cooke, John W. Draper, Willard Gibbs, and many others still living.

Present conditions in America can be measured by the fact that the American Chemical Society alone has over 7,000 members, and the Chemists' Club of New York has more than 1,000 members, without counting the more specialized chemical organizations, equally active, like the American Institute of Chemical Engineers, the American Electrochemical Society and many others.

During the later years chemical research is going on with increasing vigor, more especially in relation to chemical problems presented by enterprises which at first sight seem rather remote from the so-called chemical industry.

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[1] Journal of Ind. and Eng. Chem., vol. 5, No. 10, October, 1913.

[2] Chemistry in America, published by D. Appleton & Co. New York and London, 1914.

But the most striking symptom of newer times is that some wealthy men of America are rivaling each other in the endowment of scientific research on a scale never undertaken before, and that the scientific departments of our Government are enlarging their scope of usefulness at a rapid rate.

But we are merely at the threshold of that new era where we shall learn better to use exact knowledge and efficiency to bring greater happiness and broader opportunities to all.

However imposing may appear the institutions founded by the Nobels, the Solvays, the Monds, the Carnegies, the Rockefellers and others, each of them is only a puny effort to what is bound to come when governments will do their full share. Fancy that if, for instance the Rockefeller Institute is spending to good advantage about half a million dollars per annum for medical research, the chewing-gum bill of the United States alone would easily support half a dozen Rockefeller Institutes; and what a mere insignificant little trickle all these research funds amount to if we have the courage to compare them to that powerful gushing stream of money which yearly drains the war budget of all nations.

In the meantime the man of science is patient and continues his work steadily, if somewhat slowly, with the means hitherto at his disposal. His patience is inspired by the thought that he is not working for to-day, but for to-morrow, He is well aware that he is still surrounded by too many "men of yesterday," who delay the results of his work.

Sometimes, however, he may feel discouraged that the very efficiency he has succeeded in reaching at the cost of so many painstaking efforts, in the economical production of such an article of endlessly possible uses as Portland cement, is hopelessly lost many times over and over again by the inefficiency, waste, and graft of middlemen and political contractors, by the time it gets on our public roads, or in our public buildings. Sometimes the chaos of ignorant brutal waste which surrounds him everywhere may try his patience. Then, again, he has a vision that he is planting a tree which will blossom for his children and will bear fruit for his grandchildren.

In the meantime, industrial chemistry, like all other applications of science, has gradually called into the world an increasing number of men of newer tendencies, men who bear in mind the future rather than the past, who have acquired the habit of thinking by well-established facts, instead of by words, of aiming at efficiency instead of striking haphazard at ill-defined purposes. Our various engineering schools, our universities, are turning them out in ever-increasing numbers, and better and better prepared for their work. Their very training has fitted them out to become the most broad-minded progressive citizens.

However, their sphere of action, until now, seldom goes beyond that of private technical enterprises for private gain. And yet, there is not a chemist, not an engineer, worthy of the name, who would not prefer efficient, honorable public service, freed from party politics, to a mere money-making job.

But most Governments of the world have been run for so long almost exclusively by lawyer politicians, that we have come to consider this as an unavoidable evil, until sometimes a large experiment of government by engineers, like the Panama Canal, opens our eyes to the fact that, after all, successful government is—first and last—a matter of efficiency, according to the principles of applied science.

Was it not one of our very earliest American chemists, Benjamin Thompson, of Massachusetts, later knighted in Europe as Count Rumford, who put in shape the rather entangled administration of Bavaria by introducing scientific methods of government?

Pasteur was right when one day, exasperated by the politicians who were running his beloved France to ruin, he exclaimed:

> In our century, science is the soul of the prosperity of nations and the living source of all progress. Undoubtedly, the tiring daily discussions of politics seem to be our guide. Empty appearances! What really leads us forward are a few scientific discoveries and their application.

EXPLOSIVES.

By Maj. Edward P. O'Hern,
Ordnance Department, United States Army.

[With 7 plates.]

IMPORTANCE.

The importance of the so-called explosives and the increasing extent of their use are evident from the fact that the production in the United States for the year 1910, as shown by the United States Census reports, amounted to the enormous total of approximately 480,000,000 pounds, this being more than double the production of 1905, and more than three and one-half times that of 1900.

The increasing demand has come, not only from an ever widening field of commercial use, such as for mining, quarrying, tunneling, and road building, but from a greatly enlarged field of use for war purposes, such as for mines, torpedoes, explosive projectiles, and propelling charges. It is the purpose of the writer to discuss some of the more important explosives, their uses, the method of their employment, and the results accomplished.

GENERAL CHARACTER.

An explosive is a substance of which the molecules are made up of a number of atoms or units rather loosely bound together in an unstable condition, ready to seek new and simpler combinations upon the furnishing of a sufficient motive force to start the operation. This is usually supplied through a primer ignited by a slow-burning fuse, or by a wire heated by an electric current. When started, the heat and shock developed will cause a continuation of the action throughout the mass of the explosive. The enormous power that can thus be developed from a comparatively small quantity of material is indicated by the accompanying illustration showing the thousands of fragments into which a 12-inch armor-piercing projectile was broken by the detonation of a bursting charge of about 5½ per cent of its weight (pl. 1).

TYPES OF EXPLOSIVES.

For convenience of consideration, explosives may be divided into three general classes, viz:

1. Progressive or propelling explosives (low explosives).
2. Detonating explosives (high explosives).
3. Detonators (fulminates).

The first of these includes black gunpowder, smokeless powder, and black blasting powders; the second includes dynamite, nitroglycerin, guncotton, most of the "permissible explosives," and some blasting powders; the third class comprises chiefly fulminates and chlorates.

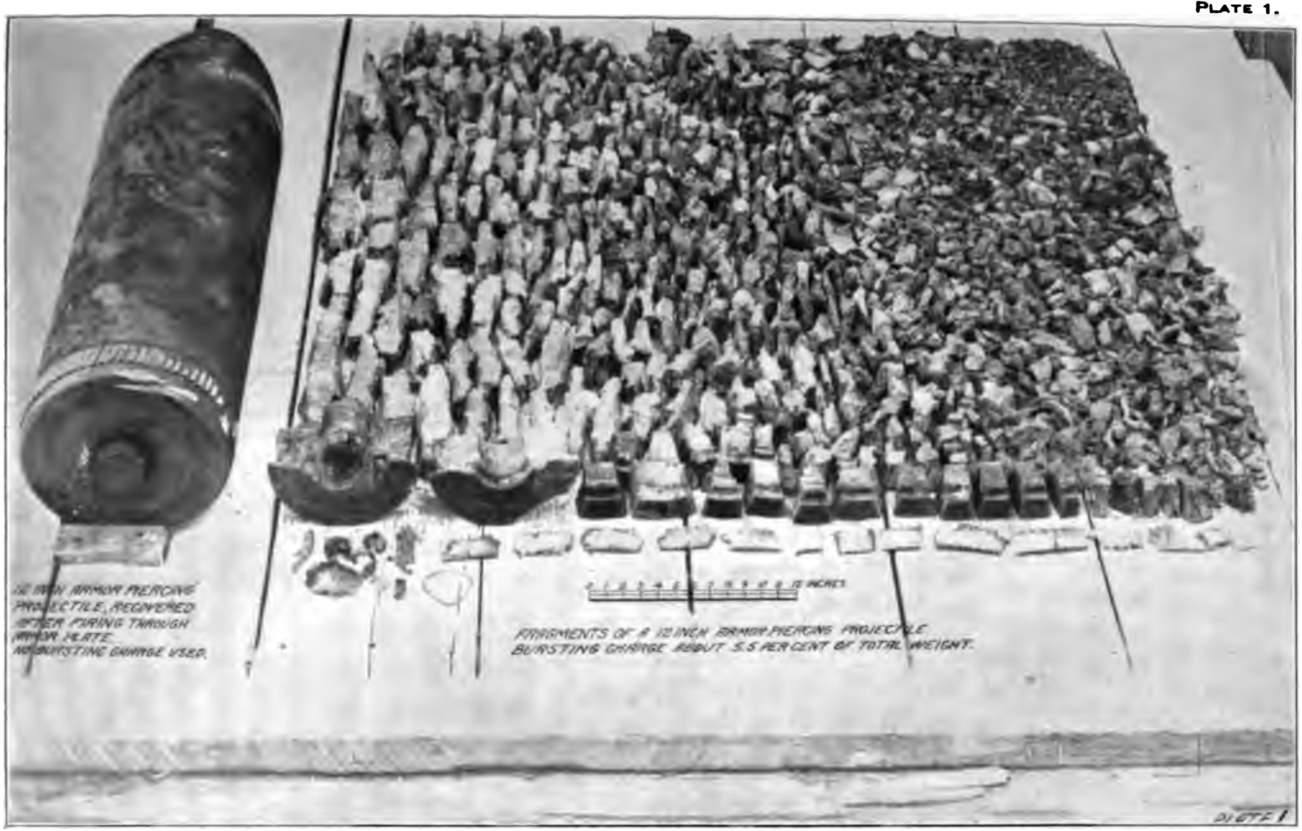
For all classes the effect of explosion is dependent upon the quantity of gas and heat developed per unit of weight and volume of the explosive, the rapidity of the reaction, and the character of the confinement, if any, given the explosive charge.

Low explosives.—The rapidity of reaction varies greatly with different explosive substances and with the manner in which the explosion is started. For certain explosives, such as smokeless powder, the explosion does not differ in principle from the burning of a piece of wood or other combustible. The combustion is very rapid but is a surface action proceeding from layer to layer until the grain is consumed. Such materials are known as low or progressive explosives, although the total power developed through the combustion of a unit weight may be very great and would be destructive unless properly controlled.

High explosives.—The combustion of another class of materials called high explosives is extremely rapid when suitably inaugurated, such action being known as a detonation.

In these explosives, such as nitroglycerin, guncotton, the picrates, etc., the progress of the explosive reaction is not by burning from layer to layer, as described above, but the breaking up of the initial molecules gives rise to an explosive wave which is transmitted with great velocity in all directions throughout the mass and causes its almost instantaneous conversion into gas. The velocity of propagation of the detonating wave has been determined for some materials to be more than 20,000 feet per second, or, approximately, 4 miles per second. A charge 1 foot long would thus be converted into gas in the very short interval of five one hundred thousandths of a second. The progressive emission of gas from a low explosive such as burning gunpowder produces a pushing effect upon a projectile throughout its movement without necessarily overstraining the gun, whereas the sudden conversion of an equal weight of material into gas, as would happen with a high explosive such as dynamite or nitroglycerin would develop such high pressure and shattering effect as to rupture the gun.

Fulminates.—The action of fulminates is much more brusque and powerful than even that of the class of explosives just described. As they can be readily detonated by shock or by the application of heat, they are used in primers and fuses to start the action of both the low and the high explosives. The most common fulminate is made by dissolving the metal mercury in strong nitric acid and pouring the solution into alcohol. After an apparently violent reaction there is


12 INCH ARMOR PIERCING
PROJECTILE, RECOVERED
AFTER FIRING THROUGH
ARMOR PLATE.
NO BURSTING CHARGE USED.
0 1 2 3 4 5 6 7 8 9 10 11 12 INCHES
FRAGMENTS OF A 12 INCH ARMOR PIERCING PROJECTILE
BURSTING CHARGE ABOUT 5.5 PER CENT OF TOTAL WEIGHT.
DIGTF 1

FRAGMENTS OF A 12-INCH ARMOR-PIERCING PROJECTILE. BURSTING CHARGE ABOUT 5.5 PER CENT OF TOTAL WEIGHT.

produced a mass of fine, gray crystals of fulminate of mercury. The crystalline powder thus produced is washed with water to free it from acids, and, because of its extreme sensitiveness, is usually kept soaked with water or alcohol until needed. On account of its great specific gravity (4.4) a small volume of it develops a large volume of gas. According to the usually assumed reaction the gas developed occupies, at the ordinary temperature, a volume more than 1,340 times that of the original material. Because of the large amount of heat developed in the reaction, the volume at the temperature of the reaction is very much greater. It is estimated that a pressure as great as 48,000 atmospheres is produced by the detonation of mercury fulminate.

QUANTITY AND COST.

According to a bulletin of the Census Bureau, approximately 487,000,000 pounds of explosives were produced in the United States during the year 1909 and comprised (approximately) the following principal items:

	Pounds.
Dynamite	195,000,000
Blasting powder	233,000,000
Nitroglycerin	29,000,000
Gunpowder	13,000,000
"Permissible explosives"	10,000,000
Smokeless powder	6,000,000
Guncotton, etc	1,000,000

The approximate value of these explosives per pound is as follows:

	Cents.
Blasting powder	4
Permissible explosives	9
Dynamite and nitroglycerin	11
Gunpowder	14
Smokeless powder	68

All of the foregoing explosives were used for industrial purposes except the smokeless powder, some of the guncotton, and some of the gunpowder. The so-called "permissible explosives" are those approved by the United States Bureau of Mines as being suitable for use in mines where dust or gas explosions are likely to occur. The explosives used for military and naval purposes probably comprised not much more than 7,000,000 out of 487,000,000 pounds, or about 1.5 per cent. Of the total money value, amounting to approximately $38,000,000, about 10 per cent represents military and naval uses.

EXPLOSIVES IN WAR.

At no time in the history of the world have explosives played such a mighty part in deciding the destiny of nations as they are playing to-day in the prosecution of the general European war. Their extensive use in the mighty engines of destruction such as the submarine mine, the torpedo, and in projectiles thrown from cannon to great distances with marvelous accuracy, is resulting in loss of life and destruction of property on an unprecedented scale.

BLACK POWDER.

Black powder is extensively used for blasting and mining purposes, but has lost its importance as a propellant in modern firearms, although still retained for primers and other special purposes supplemental to the more important smokeless powder.

Black gunpowder has, however, played a very important part in the history of the wars of the past three centuries, and for that reason deserves more than brief mention. It is ordinarily composed of about 75 parts niter, 15 parts charcoal, and 10 parts sulphur. The niter furnishes the oxygen to burn the charcoal and sulphur. The charcoal furnishes the carbon and the sulphur gives density to the grain, and lowers its point of ignition. The earliest record of the use of a mixture of this general character in actual war dates back to the fourteenth century, but its use did not become common until about the beginning of the sixteenth century. Until about the end of that century it was used in the form of fine powder; hence the name. To overcome the difficulty experienced in loading small arms from the muzzle with such material, it was given a granular form. Little further marked improvement was made until about 1860, when Gen. Thos. Rodman, of the Ordnance Department of the United States Army, advanced the principle that the rate of combustion, and consequently the pressure developed, could be controlled by compressing the fine-grained powder previously used into larger grains of greater density. The size of grain was to be so proportioned to the size and length of the gun that the powder would be completely burned up about the time the projectile reached the muzzle.

The increase in size of grain decreased the initial burning surface for a given weight of charge, thereby lowering the rate at which the gas was given off during the early part of the movement of the projectile and correspondingly lowering the maximum pressure. This permitted the use of a bigger charge, without overstraining the gun, and thus secured higher average pressures along the bore with resultant higher muzzle velocities. This principle is of special importance because it has found application in the manufacture of all the later gunpowders.

BROWN POWDER AND SMOKELESS POWDER.

A further reduction in the velocity of combustion of powder was obtained about 1880 by the substitution of an underburnt charcoal for the black variety previously used. The resulting product was called brown or cocoa powder from its appearance. The next great step in the improvement of powder was the development of smokeless powder which began to be introduced into service about 1886. The great advance that has been made in the power and range of guns since about 1880, when modern guns and powders began to be used, is evident from a comparison of the 15-inch smooth-bore gun then in use with the 14-inch rifles now being mounted. The old 15-inch gun fired a projectile weighing 450 pounds, with a muzzle velocity of 1,534 feet per second, and attained a maximum range of approximately 5,579 yards when fired at 20° elevation, the usual limit permitted by the mount. The present 14-inch gun fires a projectile weighing 1,660 pounds, with a muzzle velocity of 2,360 feet per second and attains a maximum range of approximately 19,300 yards with 15° elevation. The muzzle energy of the former projectile is approximately 7,350 foot-tons, while that of the latter is approximately 64,170 foot-tons. The former carried a small bursting charge of black powder, and would have been practically useless against modern armor, while the latter carries a large charge of powerful high explosive and is capable of getting through the heaviest armor if it strikes fairly.

SMOKELESS POWDERS.

As already pointed out, a great advance in power of firearms was made when smokeless powders came into general use. Many different kinds of such powders have been manufactured, and more or less extensively used, but all of them have practically disappeared from military use except two, the kinds commonly designated as nitrocellulose powders and nitroglycerin powders, respectively. The use of the two types is quite evenly divided. Thus, the nitrocellulose type is used by the United States Army and Navy, by the French Army and Navy, and by the German Army, whereas nitroglycerin is used by the British Army and Navy, and by the German Navy.

Nitrocellulose powders, the manufacture of which will be described more in detail later, are essentially composed of nitrocellulose or guncotton dissolved in a mixture of ether and alcohol, then compressed into a horny mass, formed into grains of suitable size, then dried until nearly all of the solvent has been extracted. The principal ingredient of nitroglycerin powder is also guncotton, the other important ingredient being nitroglycerin, this varying from 20 to 50 per cent. Guncotton, technically known as nitrocellulose, is therefore the principal ingredient of all military powders, and its manufacture is, for that reason, of special interest.

Nitrocellulose.—Nitrocellulose is obtained by the nitration of cellulose. The latter is not a clearly defined substance, but a generic term applied to a class of substances which have many chemical and physical characteristics in common. The composition of the cellulose corresponds to the empirical formula $C_{24}H_{40}O_{20}$. In the process of nitration, a number of atoms of hydrogen are replaced by a number of molecules of nitric peroxide (NO_2) giving a product nitrocellulose of the general formula $C_{24}H_{40-n}O_{20}(NO_2)_n$. It has been found possible to introduce more than 12 (NO_2) groups into the cellulose molecule. This gives a nitrogen content by weight equal to 14.16 per cent. The highest stable nitrocellulose contains, however, only about 13.5 per cent of nitrogen, and the one most used in the manufacture of smokeless powder contains about 12.5 per cent. The purest form of natural cellulose is cotton. This material is accordingly used almost exclusively in the manufacture of nitrocellulose for smokeless powder. The several steps in the process of manufacturing nitrocellulose may be described briefly as follows:

The cotton used is generally the short fiber which is detached from the cotton seed rather late in the process of removal. After being bleached and purified it is run through a picker, which opens up the fiber and breaks up any lumps. It is then thoroughly dried and is ready for nitration. The most generally used method of nitration is to put the cotton into a large vessel, nearly filled with a mixture of nitric and sulphuric acids. The sulphuric acid is used to absorb the water developed in the process of nitration, and which would otherwise too greatly dilute the nitric acid. After a few minutes immersion the pot is rapidly rotated by machinery and the acid permitted to escape. The nitrated cotton is washed in a preliminary way, then removed from the nitrator and repeatedly washed and boiled to remove all traces of free acid. In the process of nitration, the cotton has not changed its appearance, but has become a little harsh to the touch. As the keeping qualities are dependent upon the thoroughness with which it is purified, the specifications for powder for the United States Army and Navy require that the nitrocellulose shall be given at this stage of manufacture at least five boilings with a change of water after each boiling, the total time of boiling being 40 hours. Following this preliminary purification, the nitrocellulose is cut up into still shorter lengths by being repeatedly run between cylinders carrying revolving knives. This operation was found necessary as cotton fibers are hollow tubes making it very difficult to remove traces of acid from the interior unless cut into very short lengths. After being pulped, the nitrocellulose is given six more boilings with a change of water after each, followed by 10 cold-water washings. The completed material is known as guncotton or pyrocellulose. Before adding the solvent, the pyrocellulose must be completely freed from water. This is partly accomplished in a centrifugal wringer, but is completed by compressing the pyrocellulose into a solid block, then forcing alcohol through the compressed mass. Some of the water is thus forced out ahead of the alcohol and the remainder is absorbed by the alcohol, the operation of forcing it through the block being continued until pure alcohol appears. Ether is added to the pyrocellulose thus impregnated with alcohol, the relative proportions being about 2 parts of ether and 1 part of alcohol by volume. The amount of mixed solvent added varies between about 85 per cent and 110 per cent of the weight of the dried pyrocellulose. After the ether has been thoroughly incorporated in a kneading machine the material is placed in a hydraulic press, in which it is formed into cylindrical blocks about 10 inches in diameter and about 15 inches long. In this operation the pyrocellulose loses the appearance of cotton and takes on a dense horny appearance, forming what is known as a colloid. The colloid is transferred to a finishing press, where it is again forced through dies and comes out in the form of long strips or rods, which are cut to grains of the length required. The grains are then subjected to a drying process, which removes nearly all of the solvent and leaves the powder in a suitable condition for use. The drying process is a lengthy one, amounting to as much as four or five months for the larger grained powder. Upon completion, the powder is blended and packed in air-tight boxes.

Form of grain.—The form of grain used in the United States Army and Navy for large-caliber cannon is a cylinder containing seven longitudinal holes. Figure 1 shows the dimensions of a grain of about the size suitable for a 14-inch gun. The purpose of the holes is to cause an increase rather than a decrease in the burning surface, as the grain is consumed, the increase in the area due to their enlargement more than compensating for the decrease in the outer surfaces.

The increasing burning surface thus secured is advantageous in tending to better keep up the pressure as the volume behind the projectile increases as it moves down the bore. Abroad, smokeless powder is commonly made in the form of flat ribbons or single perforated sticks 2 or 3 feet long. Such forms have not been adopted in this country because of the fact that they do not give as much increase in surface while burning, and because of the difficulty of preventing serious warping of the long sticks in drying, whereby trouble would result in getting sufficient powder into the desired volume in loading.

Smokeless-powder charges.—For use in guns, smokeless powder is put up into charges inclosed in stout cloth made of raw silk. Each charge is subdivided into as many sections as is necessary to secure ease of handling. The charge for one round for a 16-inch gun is shown in plate 2. It weighs approximately 666 pounds, and is subdivided into six sections of about 111 pounds each, for ease of handling.

To improve the speed and uniformity of ignition, a small charge of black powder is fastened to one or both ends of each section of the charge. One of these is ignited by the flame from a primer inserted in the breech of the gun and serves to facilitate the ignition of the smokeless powder charge.

Life of smokeless powder.—The life of smokeless powder varies greatly with the conditions under which it is stored. If stored in a cool, dry climate it will remain in good condition indefinitely, but if exposed to high temperatures, especially if moisture be present, the stability life will be greatly reduced. In the manufacture of the United States Government smokeless powder there was used for a number of years a small percentage of a material called rosaniline, which gave the powder a strongly pinkish color, which gradually faded as the powder lost its chemical stability. This material did not retard the change, but merely served as an indicator that the powder was becoming dangerous.

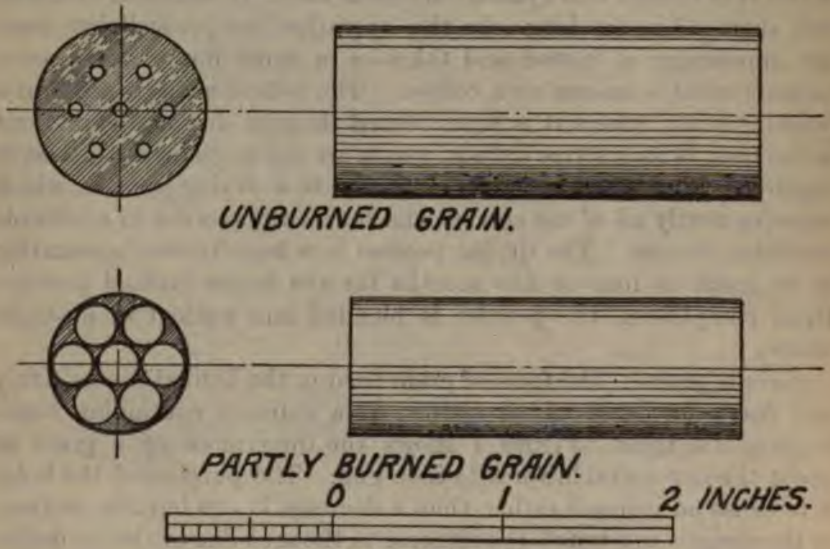
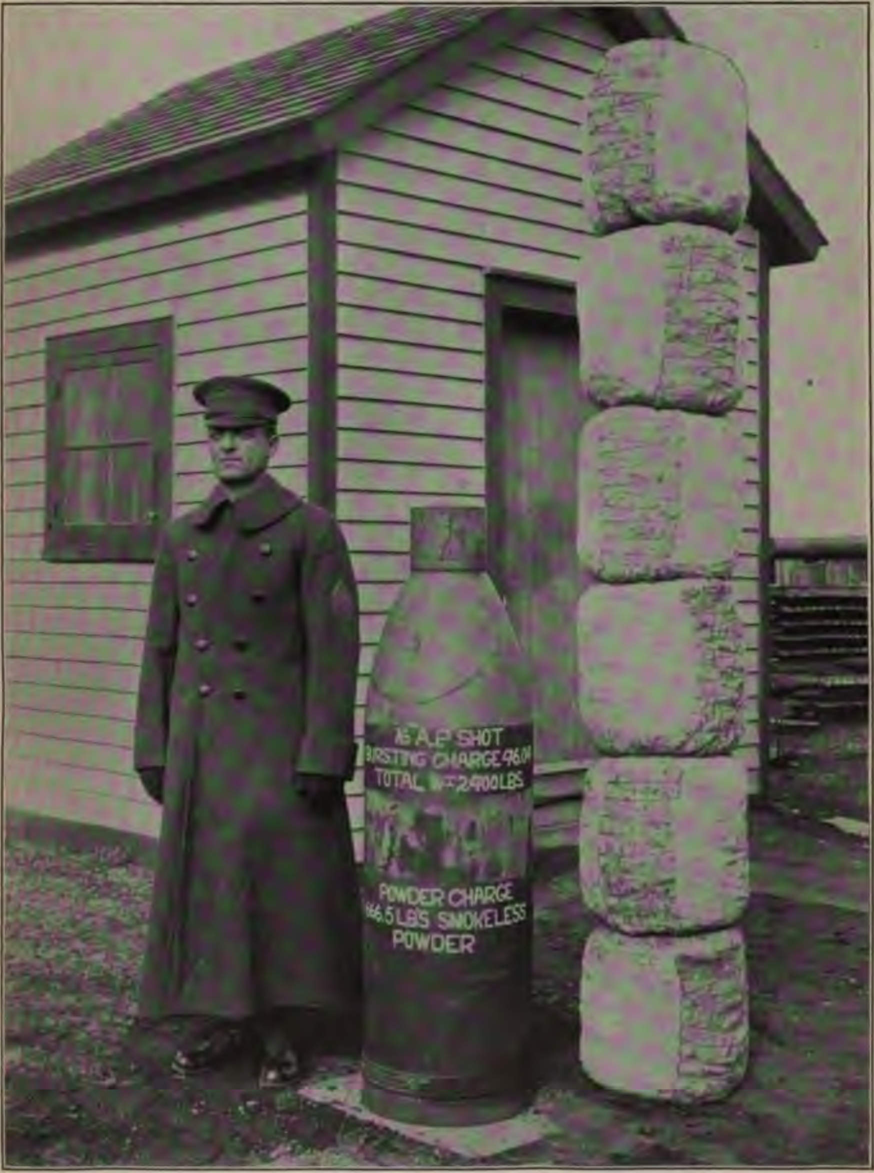
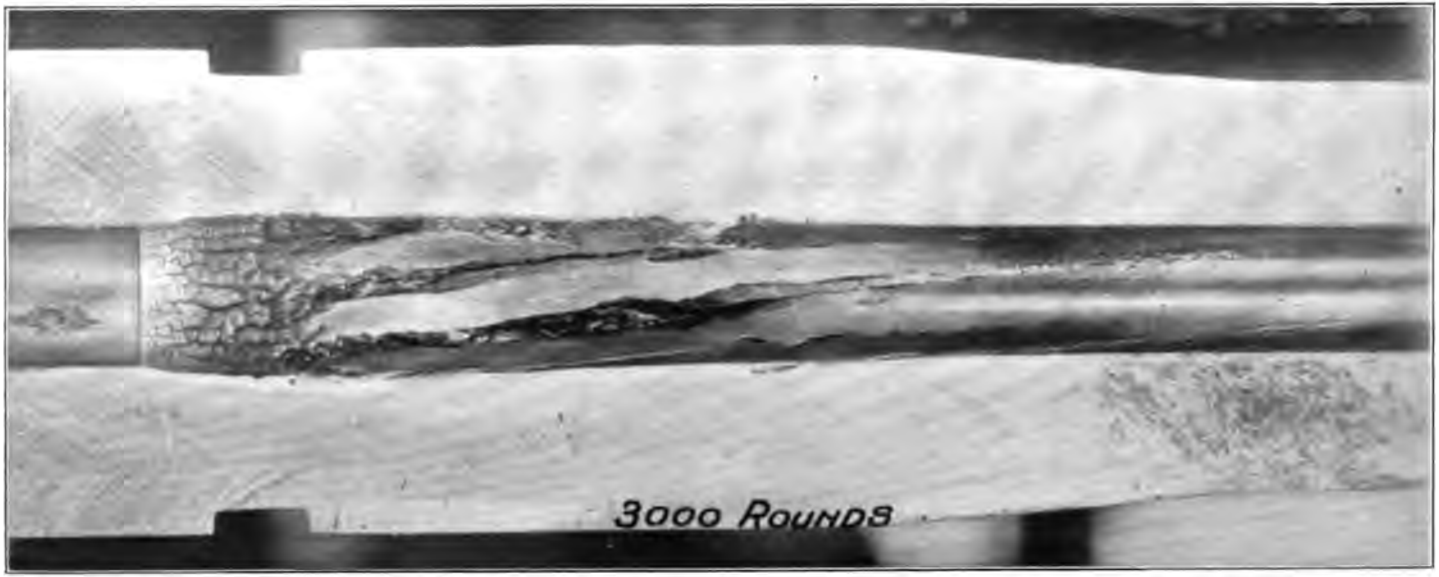


FIG. 1.—Powder grain for 14-inch gun.

About five years ago there was adopted as one of the constituents of the powder used by the United States Army and Navy a material called diphenylamine, which by combining with the products of decomposition of the smokeless powder, serves to retard the progress of decomposition, and thus greatly lengthens the stability life of the



PROJECTILE AND POWDER CHARGE FOR 16-INCH GUN. WEIGHT OF PROJECTILE, 2,400 POUNDS; WEIGHT OF POWDER CHARGE, 666.5 POUNDS OF SMOKELESS POWDER.



CROSS SECTION OF MACHINE-GUN BARREL AFTER FIRING 3,000 ROUNDS WITH NITROGLYCERIN POWDER.

powder. While there has been insufficient time since the adoption of this stabilizer to fully determine its advantages under ordinary conditions of storage, tests made at elevated temperatures have indicated that its presence will probably double the life of the powder. That the life of the smokeless powders manufactured for the United States service, even without the stabilizer, has been very satisfactory is evident from the fact that there is powder 14 years old now on hand in fairly satisfactory condition. There is a possibility that in deteriorating, the chemical action may become so violent as to cause spontaneous ignition of the powder or of the gas being developed. The Army and Navy in this country have been practically free from this source of trouble, but there have been a number of disastrous explosions from this cause abroad. Within the past few years the French have lost two battleships from this cause, the Brazilians one, and the Japanese one. In order to guard against such a possible source of danger, samples of all lots of powder are kept under constant observation at the powder factories and at storage magazines. Any serious change taking place is thus promptly detected and the corresponding lot of powder withdrawn from service.

Source of supply.—The smokeless powder needed by the United States Army and Navy is in part manufactured in Government plants and in part purchased from private manufacturers. The smokeless powder is made at all the plants, both Government and private, in accordance with specifications prepared by a joint board of Army and Navy officers, thus insuring a uniform and satisfactory product. The specifications permit the use of only the highest grade materials and prescribe such tests at the various stages of manufacture as to insure a high-grade product. The most important details of manufacture as prescribed by the specifications have been given in the discussion of the manufacture of nitrocellulose.

Tests.—The usual tests for chemical stability are made at elevated temperatures in order to bring their completion within a reasonable time limit. One of these is made with the powder at 135° C., the requirement being that the gases developed by the decomposition must not turn litmus paper to a standard red in less than 1 hour and 45 minutes, nor must any sample explode in less than 5 hours. Another test is made at 115° C., the requirement being that the loss in weight must not exceed a prescribed limit as a result of exposure to this temperature for 8 hours per day for six days. A third test is made at 65.5° C., the requirement being that no nitrous fumes shall be developed in less than a prescribed number of days, dependent upon the size of the grain being tested. To guard against brittleness, which might result in the grain being split or shattered while burning, a physical test is prescribed wherein grains are tested by being shortened in a press. The requirement in this test is that no crack shall be developed in the outer surface of the grain before it has shortened a specified percentage. Samples representing every lot of powder, lots usually consisting of 100,000 pounds, are subjected to all the foregoing tests as well as to others of less importance.

ACCURACY LIFE OF GUNS.

In order to maintain an elongated projectile in accurate flight it must be given a rapid rotation about its longitudinal axis. Except for small arms projectiles this is accomplished by means of a copper band secured to the projectile and engaging in the raised elements or rifling in the gun, this having the desired twist. In small arms the rifling engages the projectile over the entire length of the body or cylindrical part. It is found that the large powder charges and high pressures used in modern cannon rather quickly wear away the raised elements, especially near the origin, and that eventually the projectile bands fail to properly engage the rifling and the gun loses its accuracy.

With the largest caliber guns this occurs after the firing of from 150 to 250 rounds, depending upon the weights of powder charges and the muzzle velocities used, a large charge and a high muzzle velocity in general greatly shortening the accuracy life. For smaller guns the accuracy life is greater, amounting to at least 3,000 rounds for a 3-inch field gun. After a gun has lost its accuracy, it can be restored to good condition at a moderate cost by boring it out and adding a new lining tube, then rerifling the gun. One of the great advantages in the use of nitrocellulose powder, that used in this country, in comparison with the nitroglycerin powder cordite, used to a considerable extent abroad, is the much less erosive effect of the former. The great difference is evident from the fact that in changing from nitroglycerin powder to nitrocellulose powder in the United States service small arms some years ago, the accuracy life was raised from about 3,000 to about 15,000 rounds. Plate 3 indicates the condition of the interior of a 0.30-caliber machine-gun barrel after a rapid-fire test of 3,000 rounds in which nitroglycerin powder was used. The firings were made with unusual rapidity and *without the presence of the usual water jacket surrounding the barrel*, the test being one of a series in an effort to find a steel more resistant to erosion than the varieties now in use. The water-filled jacket commonly used in service firings tends to keep down the temperature of the barrel and thus reduces the erosion.

BURSTING CHARGES FOR PROJECTILES.

In selecting an explosive suitable for use as a bursting charge for projectiles, conflicting conditions are encountered in that it must be sufficiently insensitive to withstand the enormous shock in being fired from the gun, and must at the same time be sufficiently sensitive so that it will be detonated without the use of so large a detonator as would in itself be dangerous in firing. Among the more important explosives which have been tested in this country at various times for use in filling projectiles may be mentioned nitroglycerin, blasting gelatin, picric acid, emmensite, joveite, maximite, trinitrotoluol, trinitrobenzine, and wet guncotton. The extreme sensitiveness of nitroglycerin and blasting gelatin were found to render their use exceedingly dangerous, and resulted in one instance in the destruction of a $50,000 gun. Most of the other explosives mentioned were found too sensitive, too hygroscopic, or otherwise objectionable. While picric acid itself has not been greatly used, it has been employed mixed with other substances such as nitronaphthaline, nitrotoluol, nitrobenzole, camphor, etc., and these mixtures have been used under various names such as lyddite, ecrasite, melenite, shimose, maximite, etc. The explosive used in the United States service is a secret known only to those officials concerned in its procurement and use. It is designated as "Explosive D" as a tribute to its inventor, Lieut.-Col. B. W. Dunn, an officer of the Ordnance Department of the Army. This explosive can be readily manufactured and at a moderate cost, has excellent keeping qualities, can be easily loaded into projectiles, and is very powerful when detonated. It is so insensitive that it can be not only fired from a gun with absolute safety, but will withstand the shock of impact on the hardest armor plate without exploding.

ARMOR-PIERCING PROJECTILES.

The sketch (fig. 2) shows the general construction of a modern projectile used for the attack of armor. The long-pointed outer covering for the head serves to greatly reduce the air resistance encountered in flight, and thus enables the projectile to reach the target with a higher striking velocity. The short inner cap is found to give the point such support as to greatly improve the chances for the projectile's getting through a hard-faced plate unbroken. The head of the projectile proper is very hard, and at the same time very tough, two conflicting requirements.

The difficult character of the acceptance tests for armor-piercing projectiles is evident from the fact that they are in general required to perforate unbroken a hard-faced armor plate at least as thick as the caliber, or projectile diameter. A 14-inch projectile is thus

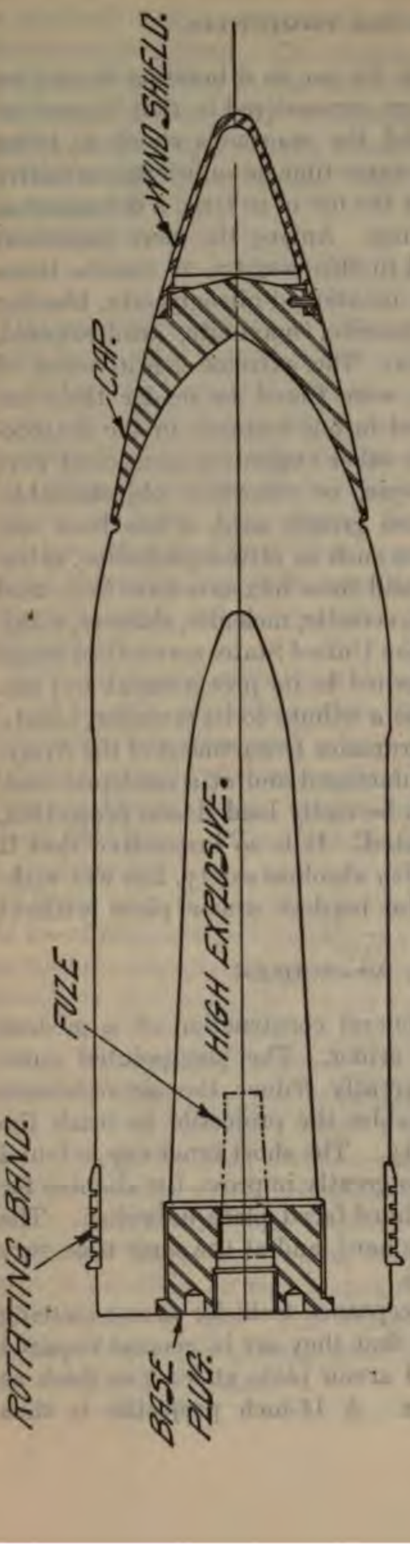


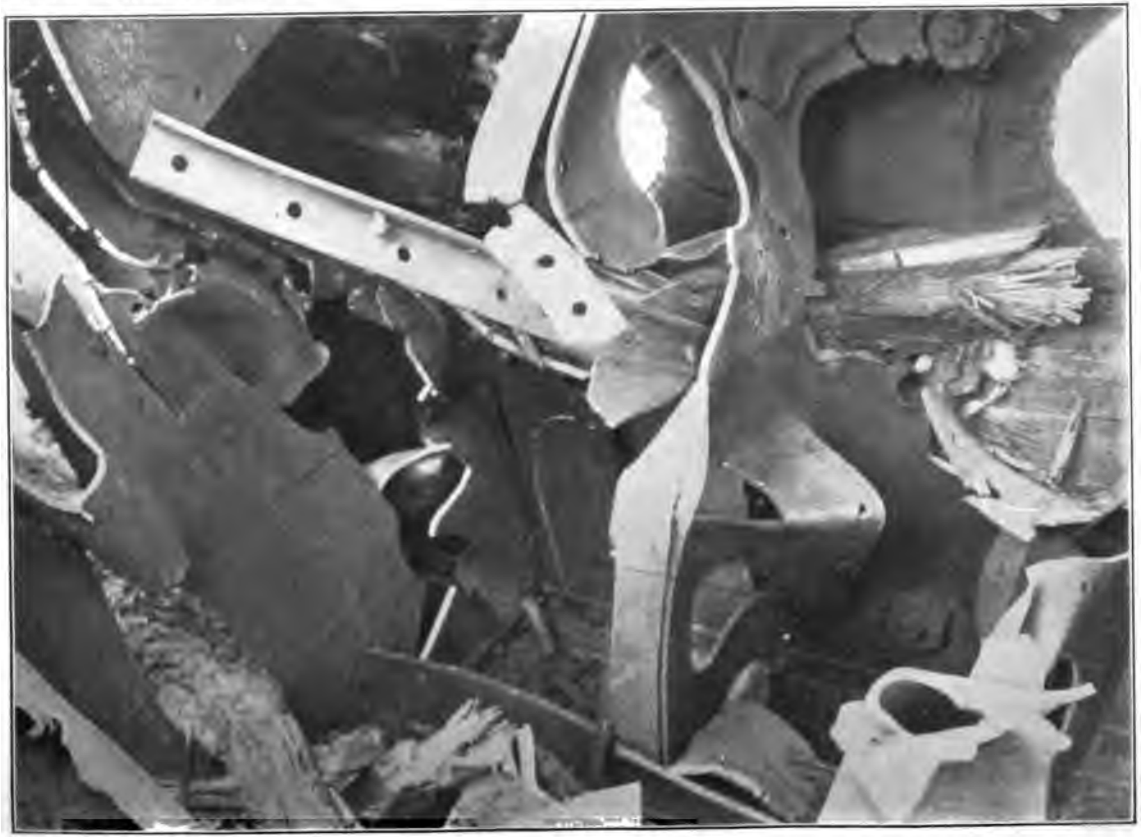
FIG. 2.—Armor-piercing projectile.

required to completely perforate a 14-inch plate, and be in unbroken condition. The striking velocity for such a test is about 1,745 feet per second.

For coast-defense guns two general types of such projectiles are employed. One of these, known as armor-piercing shell, carries a very large bursting charge and is equipped with a quick-acting fuse which detonates the explosive immediately upon impact with an armor plate (pl. 4). This type is intended for the attack of lightly armored vessels, or the upper works of heavily armored craft, and does its work by driving in the thin plates and destroying parts that are not protected by heavy armor. The other type, known as an armor-piercing shot, is thick walled and carries a smaller bursting charge. It is provided with a delay-action fuse which permits the projectile to pass through a plate and detonate after reaching the interior of a ship. Plate 5 shows the effect of such a projectile fired against a target representing a section of a fairly modern battleship. This projectile passed through 11 inches of the most modern armor and detonated some distance in rear with the result shown in the illustration. It is evident that no human being could survive within that part of the ship.

HIGH-EXPLOSIVE PROJECTILE DETONATING ON THE FACE OF AN ARMOR PLATE.

PLATE 5.



INTERIOR OF TARGET REPRESENTING SECTION OF A BATTLESHIP AFTER TWO ROUNDS OF ARMY PROJECTILES.

MOBILE ARTILLERY PROJECTILES.

There are being used by the field and siege artillery in the present European conflict three general types of explosive projectiles, viz, high-explosive shell, common shrapnel, and high-explosive shrapnel. These projectiles vary in weight from about 15 pounds, as used in guns of about 3-inch caliber, the most numerous type, to about 1,700 pounds, as used in 16.5-inch mortars, presumed to have been employed in the attack on some of the Belgian fortifications. All of these projectiles can be thrown with remarkable accuracy to a distance of at least 4 miles, while some of them, as fired from the most powerful weapons, have a range as great as 7 miles.

HIGH-EXPLOSIVE SHELL.

The high-explosive shell carry from about 3 per cent to about 30 per cent of their weight in high explosive. The smaller percentage is found in those intended for use where fragments of considerable size are needed, as for man-killing purposes in the open. The large-capacity type is used where the desired purpose is to demolish buildings, earthworks, or other obstacles. High-explosive shell are usually equipped with a fuse which will cause them to explode upon impact, but with sufficient delay to secure penetration well into the interior of trenches or other hostile cover (fig. 3). It has been reported that high-explosive shell are being used in the present European conflict to a greater extent than ever before in modern war, this condition resulting from the fact that well-prepared trenches are being utilized to a greater extent than formerly (pl. 6).

Some of the high-explosive shell fired against the armored forts in Belgium are presumed to have carried as much as 400 or 500 pounds of high explosive. The great destruction wrought by such large quantities of high explosive has been evident from the photographs published in current periodicals showing overturned or otherwise damaged turrets, and large masses of broken concrete.

COMMON SHRAPNEL.

The projectile most frequently used in land warfare, especially in the attack of troops in the open, is known as the common shrapnel. It consists essentially of a steel case closed at the rear, filled with lead balls, and carrying a fuse capable of being set to cause the balls to be expelled while the projectile is in the air immediately in front of the position occupied by the enemy. The balls are expelled by the action of a charge of powder carried in the case in the rear of the balls, and ignited by a flame from the fuse passing down a central tube communicating with the powder charge. The number of lead

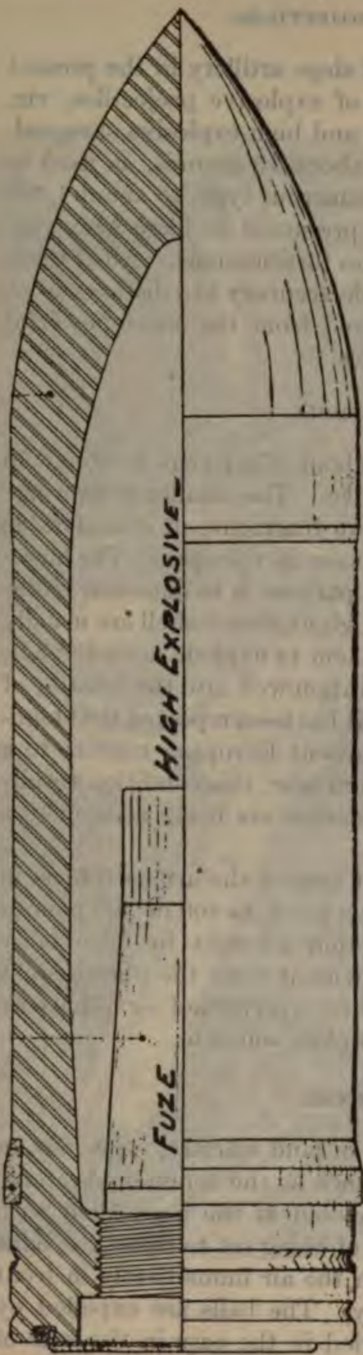


FIG. 3.—Part section through a high-explosive shell.

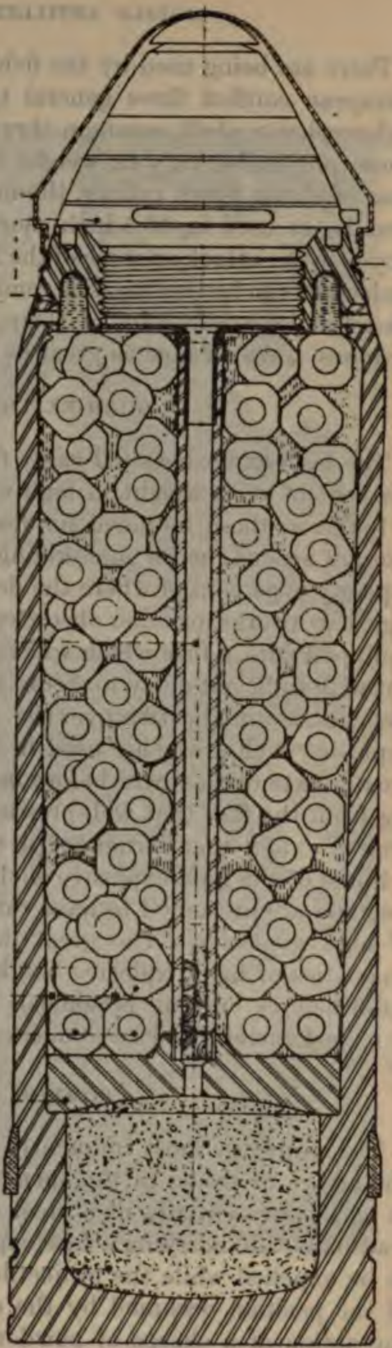


FIG. 4.—3-inch common shrapnel.

balls carried varies from about 300 in a 3-inch field-gun shrapnel to about 1,100 in a 6-inch howitzer shrapnel. Each of these balls has sufficient energy to disable a man or a horse up to 100 yards or more beyond the point of burst of the shrapnel. This type of projectile was invented about the year 1800 by a British officer, Col. Shrapnel, hence its name. The rapid rotation of the projectile in flight causes the balls to spread in a rather uniform manner, thus covering with considerable regularity a given area beyond the point of burst. In firing, an effort is made to secure a height of burst which will give a ball density of about one ball per square yard on the surface of the ground, this being sufficient to insure the escape of no one within the beaten zone unless protected by sufficient cover. A shrapnel of the type manufactured for use in the United States Army is shown in the illustration herewith (fig. 4). In order to render the point of burst more clearly visible to the firing battery and thus permit adjustment of range, the shrapnel balls are embedded in a matrix of material which gives a cloud of dense black or white smoke at the point of burst. The materials in common use for this purpose are resin, mononitronaphthalene and plain naphthalene. The cartridge case used to carry the propelling charge of smokeless powder is shown in figure 5.

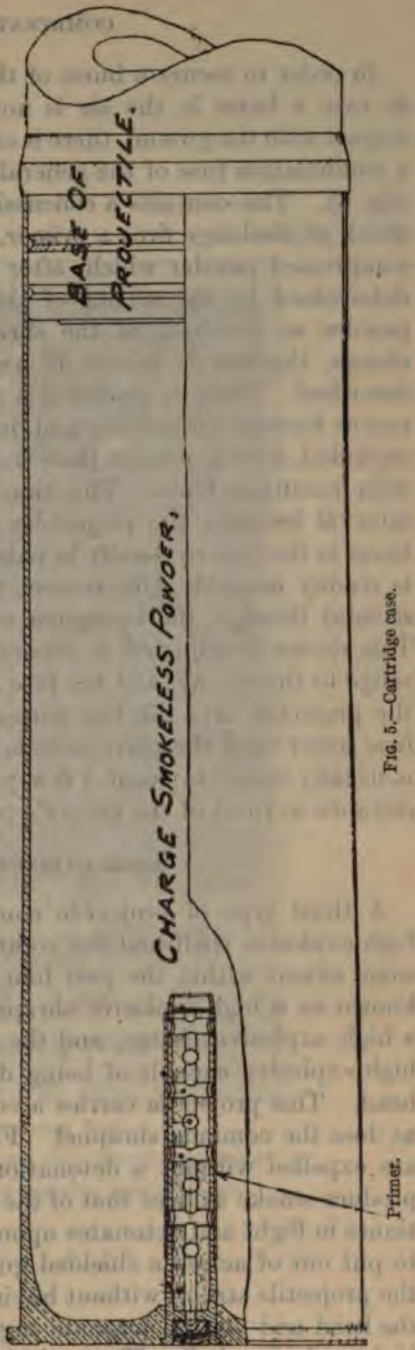


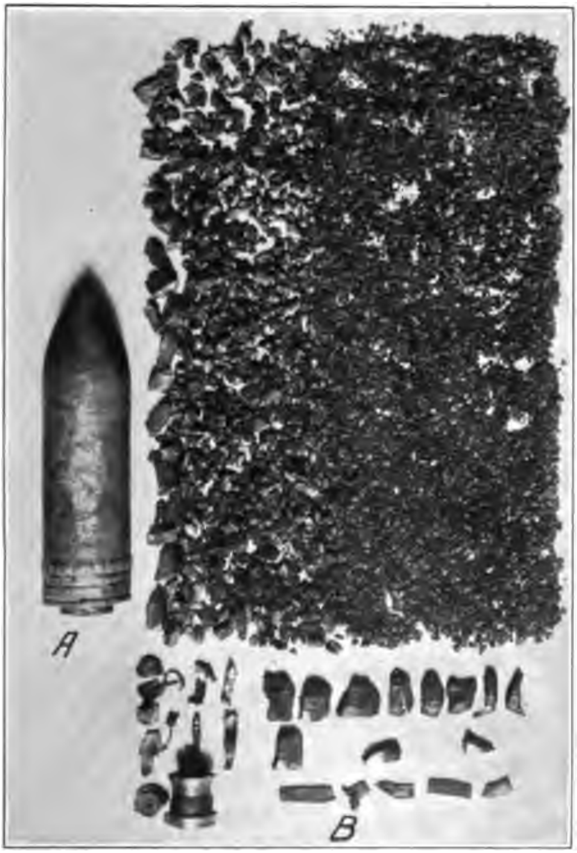
FIG. 5.—Cartridge case.

COMBINATION FUSES.

In order to secure a burst of the shrapnel at the desired range, or in case a burst in the air is not secured, to obtain a burst upon impact with the ground, there is carried on the head of each projectile a combination fuse of the general character shown in the illustration (fig. 6). This contains a concussion plunger which, by means of the shock of discharge fires a primer, and thus ignites a train or ring of compressed powder which, after burning a prearranged distance as determined by the setting of the fuse, transmits the flame to the powder at the base of the shrapnel. Upon the ignition of that charge, the fuse is driven off and the balls expelled as previously described. There is provided a second plunger—percussion—which moves forward on impact, and, in case the shrapnel has not already exploded, fires a primer that transmits a flame to the base charge with resultant burst. The time train rings which determine the interval between the projectiles leaving the gun and the point of burst in the air are usually in pairs and so arranged that one of them is readily movable with respect to the other, this movement being secured through the operation of a device called a "fuse setter." This device is adjusted in accordance with the known or supposed range to the enemy, and the fuse set accordingly by merely inserting the projectile into the fuse setter and turning the projectile or the fuse setter until the movement is automatically stopped. The burst is usually timed to occur a few yards above the ground and a short distance in front of the enemy's position.

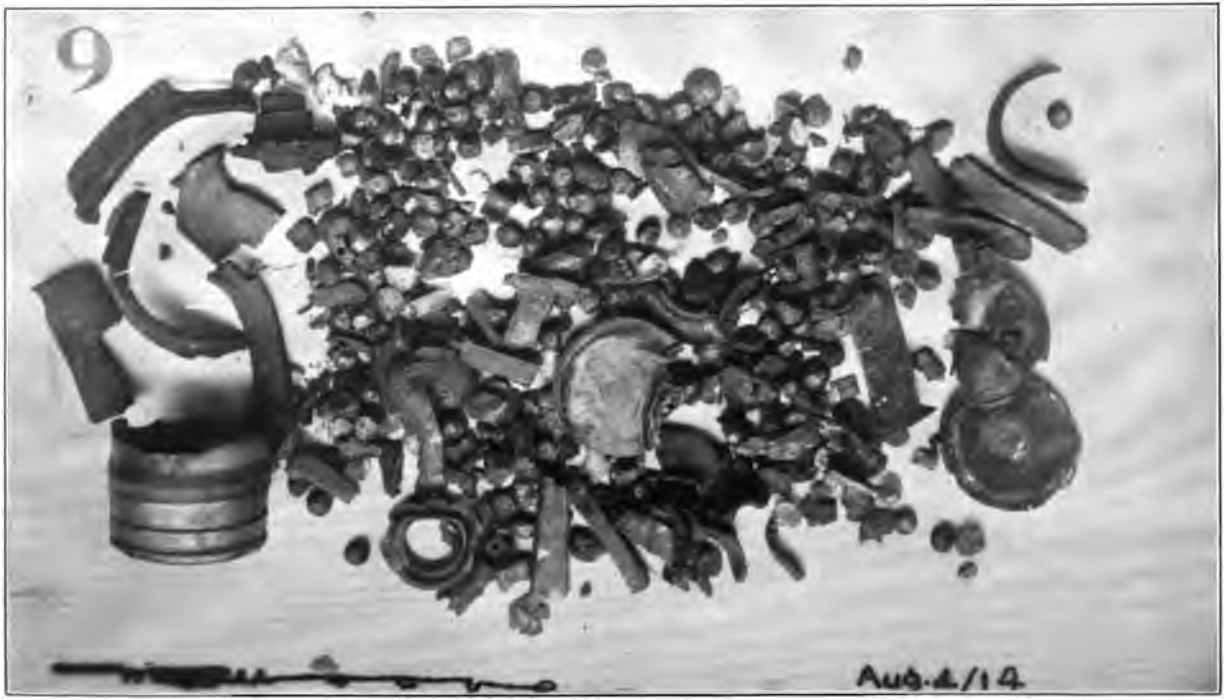
HIGH-EXPLOSIVE SHRAPNEL.

A third type of projectile combining the principles of both the high-explosive shell and the common shrapnel has come into use to some extent within the past four or five years, this projectile being known as a high-explosive shrapnel. In this type the head carries a high explosive charge, and the matrix surrounding the balls is a high explosive capable of being detonated by the detonation of the head. This projectile carries a combination fuse and a base charge as does the common shrapnel. For use as such the head and balls are expelled without a detonation occurring, the matrix serving to produce smoke as does that of the common shrapnel. The head continues in flight and detonates upon impact, the power being sufficient to put out of action a shielded gun in case it strikes the shield. If the projectile strikes without having functioned as common shrapnel, the head and matrix detonate together, thus giving the effect of the high-explosive shell. The explosive commonly used in the head and as a matrix in this class of ammunition is trinitrotoluol together with the fulminate or other similar material needed to start the deto-



3-INCH HIGH-EXPLOSIVE SHELL.

A. Shell recovered from sand butt after firing through a steel plate.
B. Fragments resulting from high-explosive bursting charge.



BALLS AND FRAGMENTS OF HEAD AND CASE, 3-INCH HIGH-EXPLOSIVE SHRAPNEL.

nation. Plate 7 shows the balls and fragments from such a projectile of 3-inch caliber weighing 15 pounds.

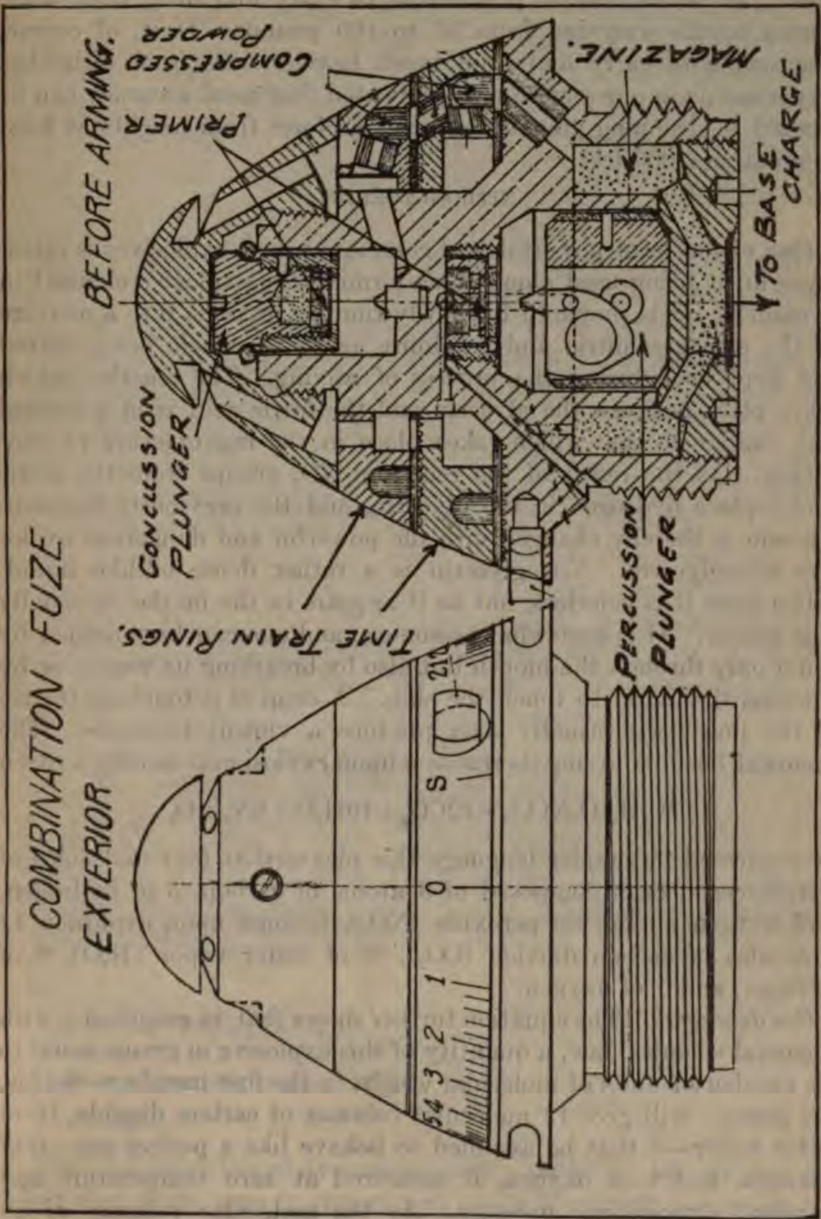


FIG. 6.—Combination fuze.

AEROPLANE BOMBS.

The usual type of bombs or grenades dropped from aeroplanes or dirigibles consist of stout envelopes containing a bursting charge of high explosive, and equipped with a fuse which operates upon impact.

These grenades are occasionally partly filled with lead balls or other missiles, but usually the effect of the high explosive alone is depended upon. It seems readily practicable to carry and drop from aeroplanes bombs weighing from 50 to 100 pounds. It is, of course, practicable to carry and drop much heavier ones from dirigibles. Experiments in our service have indicated that good accuracy can be secured in dropping grenades of suitable form from heights at least as great as 2,000 feet.

NITROGLYCERIN.

One of the most powerful and commonly used explosives is nitroglycerin, it being used alone or as forming the explosive element in dynamite. It is prepared by slowly running glycerin into a mixture of the strongest nitric and sulphuric acids, the whole being stirred and kept cool during the process of mixing. The reaction which takes place between the glycerin and the nitric acid is in a general way similar to that which takes place in the manufacture of guncotton. As the result of the reaction, NO_2 groups from the nitric acid replace hydrogen in the glycerin, and the previously harmless glycerin is thereby changed into the powerful and dangerous explosive nitroglycerin. Nitroglycerin is a rather dense oil-like liquid. When pure it is colorless, but as it appears in the market is usually pale yellow. It is somewhat poisonous, and one can be poisoned by it not only through the mouth but also by breathing its vapors or by allowing the liquid to touch the skin. A drop of it touching the tip of the finger will usually soon produce a violent headache. The chemical formula giving its reaction upon explosion is usually written

$$4C_3H_5(O.NO_2)_3 = 12CO_2 + 10H_2O + 6N_2 + O_2$$

As expressed in simpler language this means that four molecules of nitroglycerin, each composed of 3 atoms of carbon, 5 of hydrogen, 3 of oxygen and nitric peroxide (NO_2), become upon explosion 12 molecules of carbon dioxide (CO_2), 10 of water vapor (H_2O), 6 of nitrogen, and 1 of oxygen.

Gas developed.—The equation further shows that, in accordance with a general chemical law, a quantity of this explosive in grams equal to the number of units of molecular weight in the first member—that is, 908 grams—will give 12 molecular volumes of carbon dioxide, 10 of water vapor—if that be assumed to behave like a perfect gas—6 of nitrogen, and 1 of oxygen, if measured at zero temperature and standard atmospheric pressure. As the molecular volumes of all gases are the same (22.32 liters) the total volume of gas developed by 908 grams of nitroglycerin is approximately 647 liters. That is, 1 pound of nitroglycerin, which occupies approximately 16 cubic inches of space would develop approximately 340 cubic inches of gas measured under the zero temperature condition specified above, but which at the temperature of explosion would occupy more than 4,000 cubic inches, if similarly measured under atmospheric pressure.

Heat developed.—The quantity of heat developed can be readily computed from experimental data giving the heat absorbed in the formation of the explosive material and of each of the products of explosion other than the simple gases, these absorbing no heat. It is thus determined that the heat given off by exploding under constant pressure 1 pound of nitroglycerin amounts to sufficient to raise approximately 2,610 pounds of water through 1° F.

Temperature of explosion.—Knowing the quantity of heat liberated and the quantity required to raise the products of explosion through 1°, the temperature of explosion can be readily computed. The temperature thus determined for the explosion of nitroglycerin has the enormous value of approximately 3,178° C., this temperature being approximately twice that of molten steel. The considerable volume of gas developed, the very high temperature to which raised, and the quickness of the reaction account for the extremely violent action of nitroglycerin and other explosives of similar character.

DYNAMITE.

Dynamite consists of nitroglycerin absorbed in a solid body called the "dope." One of the earliest dynamites was made by absorbing nitroglycerin in powdered "rotten stone." As the rotten stone could neither burn nor explode, it was called "inactive dope." There are now many varieties of dynamites with dopes of this character. On the other hand, nitroglycerin may be absorbed in gunpowder or in other active materials which will explode as well as the nitroglycerin when the dynamite is fired. There are large numbers of dynamites thus made with active dopes, and with varying percentages of nitroglycerin. The following may be taken as an example of a standard dynamite with an active dope:

	Per cent.
Nitroglycerin	40
Nitrate of soda (sodium nitrate)	44
Wood pulp	15
Carbonate of lime (calcium carbonate)	1
Total	100

The extensive use of dynamite in this country is apparent from the fact that there were manufactured in the United States in the year 1909, as previously stated, approximately 195,000,000 pounds of this material. It was the explosive most largely used in digging the Panama Canal, the expenditure at times amounting to about 1,000,000 pounds a month.

EXPLOSIVE GELATIN AND GELATIN DYNAMITE.

Nitroglycerin, like other liquids, acts as a solvent for certain materials. It has been found that it will dissolve nitrocellulose, and that the mixture thus formed will become a jellylike mass. In this way a substance known as explosive gelatin is formed, which material is in some respects the most nearly ideal explosive and one of the most powerful known. It is, in fact, too powerful for ordinary use in blasting and is commonly mixed with dope, such as nitrate of soda and wood pulp, as used in straight dynamite. The mixture so formed is commonly known as gelatin dynamite.

DYNAMITE CARTRIDGES.

Dynamite and other explosives containing nitroglycerin are ordinarily put upon the market in the form of sticks or cartridges, which are made by wrapping cylinders of the material in stout paper; the wrappers are paraffined to protect them against the action of the water and from moisture in the air, because the nitrate of soda, which the material commonly contains, absorbs moisture and thereby becomes damaged. The sticks of explosive vary in size from about 1 inch to 2½ inches in diameter, and are usually about 8 inches long. They are commonly packed in cases containing 50 pounds each.

NITRO SUBSTITUTION COMPOUNDS.

A number of substances derived from coal tar, if acted upon by nitric acid, form what are known as nitro-substitution compounds. The best known and most extensively used of these compounds is phenol, or carbolic acid, which material comes from the oxidation of benzine. The chief source of benzine is coal tar, from which it passes over in the fractional distillation between 150° and 200° C. In the usual process of manufacture the liquid thus obtained is treated with caustic soda, and results in the production of sodium phenylate. This is acted upon by sulphuric acid and purified by further fractional distillation, resulting in the production of phenol. Picric acid is obtained by treating phenol with nitric acid. The resultant product is not only greatly used as an explosive by itself, but as an ingredient of many explosive mixtures.

"Melenite," the high explosive used by the French for filling projectiles, is probably picric acid and colloided nitrocellulose, or some other substance, such as nitrobenzole. "Lyddite," the high explosive used by the British, is presumably likewise a mixture of picric acid and some substance of the character used with melenite. "Shimose," the high explosive used by the Japanese, is thought to be either pure picric acid or a mixture of that and a nitrate compound of the aromatic series. The high explosive used in the United States service is less sensitive than any of those referred to above, and at the same time is very powerful. Its power is indicated by the fact that the pressure developed in a projectile filled with that material is estimated to be approximately twice as great as that developed in one filled with compressed guncotton.

MEANS OF IGNITING EXPLOSIVES.

Some types of explosives, such as black powder and blasting powder, can be satisfactorily ignited by means of an ordinary flame. For blasting purposes this is commonly supplied by a slow-burning fuse consisting of a core of mealed powder inclosed in two or more layers of yarn and generally surrounded by tape that has been dipped into a waterproofing composition. A suitable length of fuse having been cut off, and one end inserted in the explosive, the other end is lighted. The powder core burns slowly along the fuse, giving the operator time to proceed to a safe distance. For other types of explosives, such as dynamite, detonators are needed to secure satisfactory starting of the explosion. These detonators, as used in commercial practice, are commonly called blasting caps, and consist of copper capsules about as thick as an ordinary lead pencil. They are commonly charged with dry mercuric fulminate, or with a mixture of such fulminate and potassium chlorate. The weight of fulminate in detonators varies from about 8 to about 30 grains. The detonators themselves are usually fired by means of a fuse of the character previously described.

ELECTRIC DETONATORS.

In order to secure greater safety for the operator, electric detonators or fuses that can be fired from a considerable distance are commonly used. These detonators differ from those previously described in that two electric wires enter the upper end and are joined by an extremely fine platinum or other high resistance wire like the carbon filament in an incandescent lamp, which becomes heated until it glows, when an electric current is passed through it. This wire, known as the bridge, is placed above the detonating composition and is surrounded by guncotton or loose fulminate. Such a detonator differs in principle from the electric primers commonly used in firing cannon only in that the mercuric fulminate of the detonator is replaced by black powder in the cannon primer.

SUBMARINE MINES.

A submarine mine is essentially a charge of high explosive confined in a strong case, and provided with a suitable fuse to cause its explosion either upon the receipt of a blow from being struck by a ship, or to be exploded electrically from a distance. A torpedo differs from a submarine mine chiefly in that it is provided with a vehicle for its transportation to a distance.

The first recorded experiments with submarine mines were made by David Bushnell, of Connecticut, in 1775. His mines contained charges of black powder and explosion was effected by means of clockwork which, after being set in motion, allowed sufficient time for the operator to get away before the explosion. Bushnell also constructed a submarine boat for the purpose of conveying his mines to hostile vessels. With such a boat an attempt was actually made in 1776 to sink the British man-of-war *Eagle* in New York harbor. An important step in the development of submarine mines was made in 1842 by Samuel Colt in applying electricity to the firing of such mines. Mines and torpedoes were first successfully used during our Civil War. Although of rather crude construction, they succeeded in sinking or seriously damaging more than 30 ships. Their success turned the attention of the world to this method of naval attack and defense, with the result that there have followed great improvements in appliances and methods.

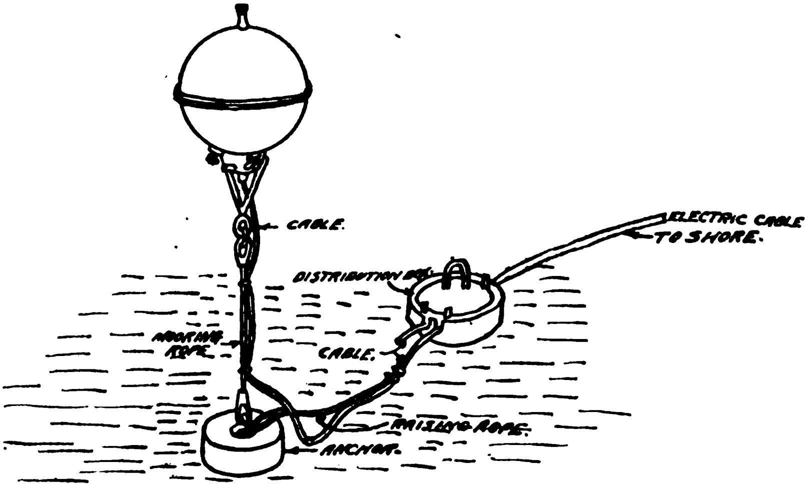


FIG. 7.—Submarine mine.

The sketch (fig. 7) shows a submarine mine of the type planted in waterways with a view to closing the entrance to harbors. Such a mine is usually controlled electrically from shore, but may be set to operate upon being struck by a passing ship. The steel case is either spherical or cylindrical, depending upon the quantity of explosive carried. The amount usually carried is from 100 to 500 pounds, although there is no special reason why even greater quantities may not be carried.

Method of firing.—For electrically-controlled mines a continuous insulated cable extends from a mining casemate in the fortification on shore to each mine in the adjacent waters. Observers are maintained to watch for the approach of hostile vessels and to plot their position with respect to the mines. The electrical system is usually so arranged that the striking of a mine is automatically signaled to the operator on shore, who may then fire it at once or after a few moments' delay in order to allow the hostile ship to get well over it. The electrical method of control permits the safe passage of a friendly vessel. Mines which are set adrift or are planted at the entrance of harbors without providing electrical control from the shore are equipped with a firing mechanism or fuse which operates upon the shock of contact with a vessel. This has the decided disadvantage that it functions equally well whether the vessel be friendly or hostile.

DEFENSIVE MINE SYSTEM.

The sketch herewith shows the general arrangement of a defensive mine system covering the entrance to a harbor. Concealed and protected in the fortifications is a mining casemate (C) which contains the electrical generators, switchboards, and instruments needed in the service of the mines. The mines are planted in small groups for convenience of cable service.

In the sketch (fig. 8) each small circle represents an individual mine. The arrangement of the mines is such that a hostile vessel can follow no reasonable course into the harbor without encountering one or more mines. Gaps forming a more or less tortuous channel are sometimes left through which friendly vessels can be conducted by guide boats. In order to prevent the enemy from removing the mines or destroying them in position and thus clearing a channel, rapid-fire guns are usually mounted to cover the mine fields and prevent the sending in of small boats or tugs to accomplish this purpose. Searchlights are provided to illuminate the mine fields and prevent such action under cover of darkness.

TORPEDO.

A torpedo is merely a mine carried at the forward end of a self-propelling vehicle. The motive power is usually compressed air stored in a tank under very heavy pressure and supplied to two propellers by means of a compressed-air motor. These propellers turn in opposite directions in order that the torpedo may not be thereby turned over. In order to secure greater power, arrangements are made to heat the air by an alcohol torch in its passage from the tank to the engine. The torpedo is discharged from a launching tube mounted on a ship's deck or built into the ship below the water line. The torpedo leaves the tube with a moderately low velocity, and is then driven forward through the water by its own propellers, operated by compressed air as previously described. The explosive charge carried in the head is fired by percussion when the torpedo strikes. The depth at which the torpedo will travel is regulated by the operation of a plunger, which is acted on by the water pressure and controls a steering device which operates a horizontal rudder attached to the rear of the torpedo (fig. 9.)

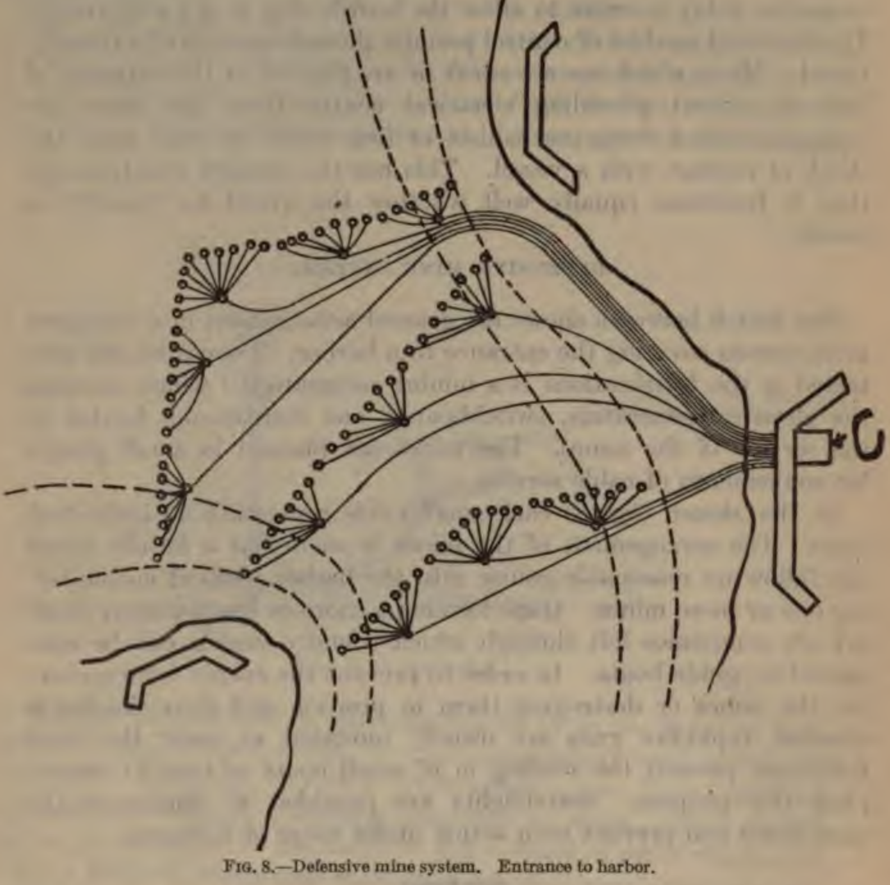


FIG. 8.—Defensive mine system. Entrance to harbor.

DIRECTING MECHANISM.

The torpedo is guided in direction through the operation of a rapidly rotating gyroscope or small wheel which controls a steering engine. This gyroscope is usually of a turbine construction and is rotated by compressed air at a very high rate of speed. In accordance with a well-known principle of mechanics, such a rapidly rotating body resists any force tending to change the direction of its axis of rotation. To insure the torpedo's following a desired direction, it is only necessary then to point the axis of the gyroscope in the proper direction before launching the torpedo. The size and effective range of torpedoes have been greatly increased within recent years. Those of late construction are as much as 21 inches in diameter, 16 feet long, have an extreme range of at least 10,000 yards, or nearly 6 miles, a maximum speed of at least 36 miles per hour, and carry a charge of as much as 300 pounds of high explosive.

EXPLOSIVES USED.

Until recently, dynamite and guncotton have been the principal explosives used in submarine warfare, but there is reason to believe that some of the important countries have adopted for that purpose the explosive trinitrotoluol or other similar explosives. Dynamite has the advantage of cheapness and ease of ignition. Its disadvantages are changing sensibility when freezing and thawing, and separation of the nitroglycerin from the absorbent if the dynamite becomes wet through leakage in the mine case. Guncotton has usually been employed wet, in which condition it is safe and insensitive, but can be detonated only by means of a priming charge of dry guncotton. The chief objection to guncotton is the danger in handling the dry primer, and its liability to become accidentally wet and thereby prevent the functioning of the mine. Trinitrotoluol has the advantage of being safe to handle and of not being affected by contact with water.

ISOLATION OF MAGAZINES.

There is no general law in this country prescribing requirements as to the character of magazines for storing explosives, nor as to the location of storage places with respect to dwellings, although there are usually State

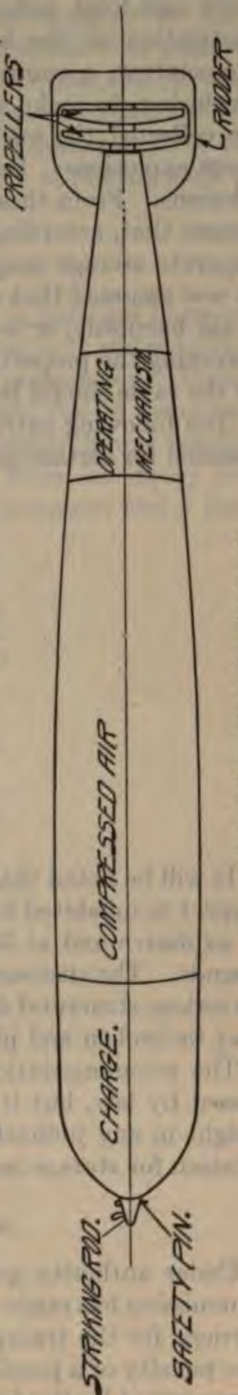


FIG. 9.—Self-propelling submarine torpedo.

laws and local police regulations governing such matters. At the instigation of the bureau of explosives of the American Railway Association, a committee was appointed by the manufacturers of explosives to make an exhaustive study of all the data that could be collected the world over to show the damage that had resulted from explosions. Data were thus collected relating to over 130 explosions. From these data a table was prepared to show the distances that, according to the quantity of explosives involved, should separate storage magazines from inhabited dwellings and railways. It was assumed that such magazines would be provided with an artificial barricade, or would have the advantage of a natural obstacle screening the property to be protected, otherwise the distances given in the table should be doubled.

The following extracts from that table show the distances recommended for certain quantities of explosives:

Quantity of explosives stored.	Proposed American distances.	
	Inhabited buildings.	Public railway.
Pounds.	*Feet.*	*Feet.*
100	180	110
500	400	240
1,000	530	320
5,000	780	470
10,000	890	535
50,000	1,460	875
100,000	1,835	1,100
500,000	2,755	1,655
1,000,000	3,455	2,075

It will be noted that a barricaded magazine is considered safe with respect to inhabited buildings at a distance of 180 feet for 100 pounds of explosive and at 3,455 feet, or about 0.6 of a mile for 1,000,000 pounds. The distance here indicated as safe means that at which no serious structural damage will be done to buildings, although glass may be broken and plaster shaken down.

The recommendations of the committee have not yet been sanctioned by law, but it seems probable that they will be given great weight in any judicial procedure involving questions as to safety of location for storage magazines.

SHIPMENT OF EXPLOSIVES.

Under authority granted by Congress, the Interstate Commerce Commission has made regulations, binding upon shippers and common carriers, for the transportation of explosives in interstate commerce. The penalty of a possible fine of $2,000 and 18 months' imprisonment is prescribed by law for a violation of these regulations. The shipper must certify on his shipping order that the explosive offered by him is in a proper condition for safe transportation and that it is packed and marked as required by the regulations. The regulations require that the car used for shipment of certain classes of explosives be placarded to clearly indicate the character of the contents so as to insure greater care in switching and the avoidance of placing such a car in a dangerous position in a train.

EXPLOSIVES IN BAGGAGE.

In order to prevent the carrying of explosives in personal baggage or on passenger cars, the law makes this a criminal act, and subjects the guilty person, when detected, to arrest and prosecution. There is prescribed a maximum penalty of imprisonment for 10 years for anyone convicted of this crime when death or bodily injury results from the illegal transportation of explosives. When no injury results, the maximum penalty is 18 months' imprisonment and a fine of $2,000.

CLIMATES OF GEOLOGIC TIME.[1]

By Charles Schuchert.

The ancient philosophers imagined that the earth arose out of darkness and chaos and that its present form and condition came about gradually through the creative acts of an omniscient and omnipotent God. Certain Greek philosophers tell us that the world had its origin in a primeval chaos; others that it arose out of water or an all-pervading primeval substance with inherent power of movement; that the energy of this primal matter determined heat and cold, and that the stars originated from fire and air. It was Empedocles (492–432 B. C.) who first told us that the interior of the earth was hot and composed of molten material, an opinion he formulated after seeing the volcanic activity of the Sicilian Mount Etna, in whose crater he is said to have met his fate.

The geology of to-day still teaches that the interior of the earth is very hot, but that the material of which it consists is as dense and rigid as steel, and that little of the interior high temperatures attains the earth's surface because of the low conductivity of the rocky and far less dense outer shell. The older geologists believed that this shell originally was thin, and that therefore much heat was radiated into space, this idea being a natural result of the Laplacian theory of earth origin. In other words, they held that the earth was once a very small star which in the course of the eons gradually cooled and formed a crust. Therefore it was postulated that, because the crust formerly must have been thin, life began in hot waters and the climates of the geologic past were hot, with dense atmospheres charged with far more carbonic acid and water vapor than they now hold. The present type of climate with zonal belts of decidedly varying temperature and polar ice caps was thought to be of very recent origin, resultant from a much thickened rocky crust. All of these conceptions are now greatly modified by the planetesimal hypothesis of Profs. Chamberlin and Moulton, which teaches of an earth accreting around a primordial cold nucleus through the infalling of small cold bodies, the planetesimals, all of this material being derived from a spiral nebular mass formed through the close approach of two large bodies. As the nuclear earth grew in dimensions, so also was increased the gravitative pressure, gradually developing central heat which spread to the surface and there broke out in a long period of volcanic activity.

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[1] Reprinted by permission, after revision by the author. The article first appeared as chapter 21 in The Climatic Factor, by Ellsworth Huntington, 1914, pp. 265-289. Published by the Carnegie Institution of Washington, as publication No. 192.

Our knowledge of glacial climates had its origin in the Alps, the land of magnificent scenery and marvelous glaciers, through the work of Andreas Scheuzer, early in the eighteenth century. This was at first only a study of the interesting local glaciers, but out of it gradually came about, especially through the studies of De Saussure, Hugi, Venetz, Charpentier, Schimper, and Louis Agassiz, the application of conditions observed in the Alps to the very widely distributed foreign bowlders known as erratics and the heterogeneous accumulations of sands, clays, and bowlders called tills. The engineer Venetz in 1821 pointed out that the Alpine glaciers had once been of far greater size, and that glaciation had been on a scale of enormous magnitude in some former period. By degrees the older conception that the erratics and tills were of flood, river, or iceberg origin gave way to the theory of colder climates and glaciers of continental extent. It was shown that the reduced temperature was finally succeeded by greater warmth, and that in the wake of the melting glaciers the land was strewn with erratics, with thick accumulations of heterogeneous rocks deposited at the edge of ice sheets and known as moraines, and with great fans of bowlder clays and sands, all of this being the diluvium or deluge material of the older philosophers and the drift or tills of modern students of earth science.

Throughout more than a century of study we have learned how glaciers do their work and what results are accomplished by their motion plus the action of temperature, air, and water. The present geographic distribution of the glaciers, together with that of the glacial deposits, shows us that during the Pleistocene or glacial period the temperature of the entire earth was lowered. We also know that this cold period was not a uniformly continuous one, but that during the Pleistocene there were no less than four intermediate warmer climates, so warm indeed that during one of them lions and hippopotamuses lived in western Europe along with primitive man. We may now be living in another interglacial warm period, though more probably we are just emerging from the Pleistocene ice age. Figure 1 gives the known distribution of Pleistocene glacial materials.

With the reduction of temperature, great variations also took place in the local supply of moisture, in the number of dark days, and in the air currents. How great these changes were in Pleistocene time is now being revealed to us through the work of the geologists, *paleontologists*, and ethnologists of Europe, where this record is far more detailed than in North America. These observations picture a fierce struggle on the part of the hardier organisms against the colder climates, a blotting out of those addicted to confirmed habits and to warmer conditions, and a driving southward of certain elements of the flora and fauna from the glaciated into the nonglaciated regions. The result was the disestablishment of the entire organic world of the Pleistocene lands other than those of the Tropics. More

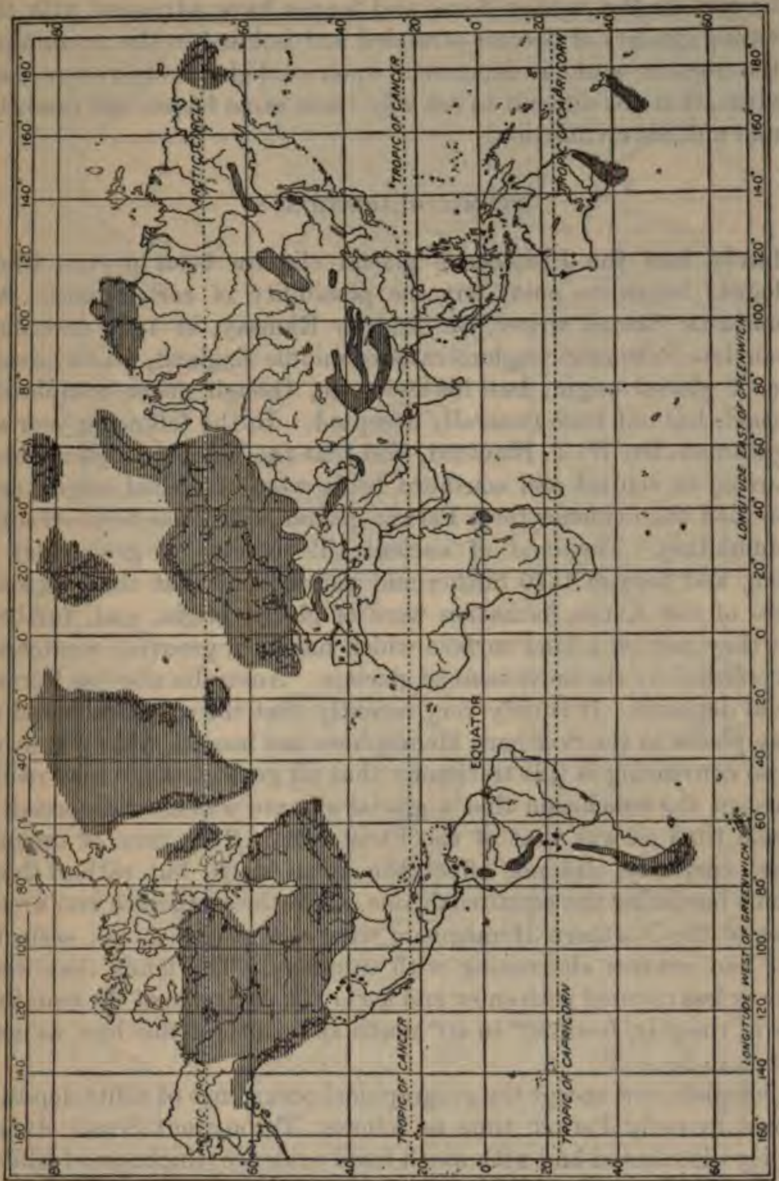

FIG. 1.—Map of Pleistocene glaciation.

than once man and his organic surroundings have been forced to wander into new regions; the life of cool to cold climates has dispossessed that of milder temperatures, and with each moderation of the climate the hardier floras and faunas have advanced with the retreating glaciers or become stranded and isolated in the mountains. As the organic world is dependent upon sunlight, temperature, and moisture, it is not difficult to see why these same factors are essential to man and his civilization.

PERMIC GLACIATION.

Hardly had the Pleistocene glacial climate been proven when geologists began to point out the possibility of earlier ones. An enthusiastic Scotch writer, Sir Andrew Ramsay, in 1855 described certain late Paleozoic conglomerates of middle England, which he said were of glacial origin, but his evidence, though never completely gainsaid, has not been generally accepted. In the following year an Englishman, Dr. W. T. Blanford, said that the Talchir conglomerates occurring in central and southern India were of glacial origin, and since then the evidence for a Permic glacial period has been steadily accumulating. The land of ancient tills (tillites of geologists) is Africa, and here in 1870 Sutherland pointed out that the conglomerates of the Karoo formation were of glacial origin, and, further, that they rest on a land surface which has been grooved, scratched, and polished by the movement of glaciers. Australia also has Permic glacial deposits. It is only very recently that the evidence found in many places in the Southern Hemisphere has become widely known, but so convincing is this testimony that all geologists are now ready to accept the conclusion that a glacial climate was as widespread in Permic time as was that of the Pleistocene. This time of organic stress, curiously, did not affect the polar lands, but rather those regions bordering the equatorial zone, while the temperate and arctic zones of the Northern Hemisphere were not glaciated, but seem to have had winters alternating with summers. The lands that were more or less covered with snow and ice lay on each side of the equator; that is, roughly, from 20° to 40° north and south of this line, as may be seen in figure 2.

Geologists now accept the geographical occurrence of tillite deposits formed in early Permic time as follows: Throughout South Africa (widely distributed and with much fossil evidence, thickness of tillites up to 1,130 feet); Tasmania; western, southern, eastern, and central Australia (tillites up to 1,300 feet thick, both land and marine fossils); peninsular and northwestern India; southeastern Brazil (of wide distribution, with land floras and some marine invertebrates); *northern* Argentina; and the Falkland Islands. "It may be added that the plant beds of the Gondwana associated with the glacial deposits found near Herat (Afghanistan) are much like beds found in Russian Turkestan and Elburz, in Armenia, suggesting a still further extension to the west (of India), and that a probably glacial conglomerate is known from the Urals." (Coleman, 1908A: 350.) Heritsch records the presence of tillites in the Alps and Frech points out that a scratched surface occurs in the Ruhr coal field of Germany, on

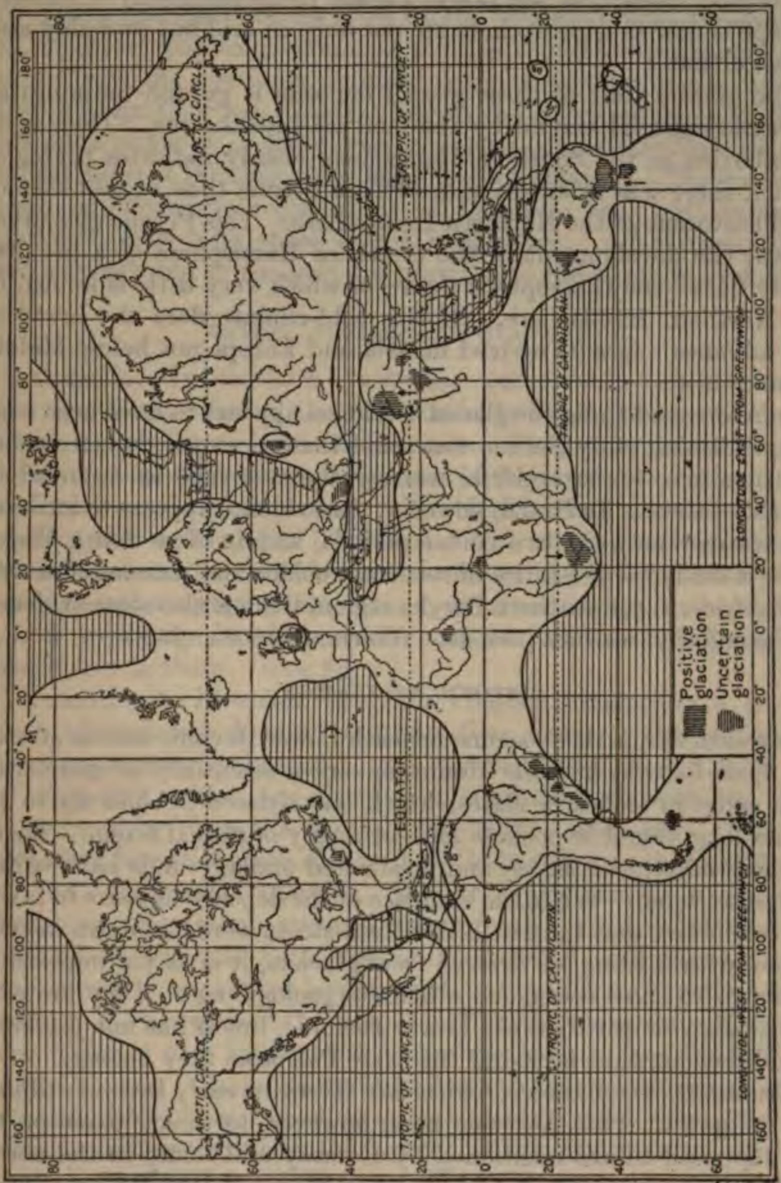

FIG. 2.—Paleogeography and glaciation of early Permic times.

which the Rothliegende rests. (Frech, 1908: 74.) The Roxbury conglomerate, with a thickness of 500 to 600 feet, occurs in the vicinity of Boston and is interpreted as a tillite. (Sayles and La Forge: 723–724.) Then, too, the Lower Permic (Buntsandstein) of western Europe is now thought to indicate not only an arid but probably also a cool climate.

The greater part of these glacial deposits is ground moraines or morainic material carried by the land ice into the sea. Their wide distribution in the Southern Hemisphere clearly indicates that glaciation there was as effective in earliest Permic time as was that of the Pleistocene of the Northern Hemisphere. This Permic glaciation caused the development in the Southern Hemisphere of a peculiar hardy flora—the Glossopteris flora—of which very little is known in the Northern Hemisphere. Of this cold-climate flora the invaders and advance migrants arrived in Asia and Europe not before Middle Permic time.

In Africa and India the glacial condition appears to have been continuous during early Permic time, and there is as yet no convincing evidence here for interglacial warmer climates such as occurred in the Pleistocene. In Brazil, however, the evidence appears to indicate one warmer between two colder periods, and in New South Wales there is evidence of a series of recurrent colder and warmer climates.

In Africa, in the southern Dwyka region, there is also some evidence for interglacial warmer periods. (Coleman, 1908A: 360.)

DEVONIC GLACIATION.

In South Africa there occurs, beneath Lower Devonic marine strata, the 5,000-foot-thick Table Mountain series, essentially of quartzites with zones of shales or slates, which has striated pebbles up to 15 inches long, found in pockets and seemingly of glacial origin. There are here no typical tillites, and no striated undergrounds have so far been discovered. While the evidence of the deposits appears to favor the conclusion that the Table Mountain strata were laid down in cold waters with floating ice derived from glaciers, it is as yet impossible to assign to these sediments a definite geologic age. They are certainly not younger than the Lower Devonic, but it has not yet been established to what period of the early Paleozoic they belong.

Elsewhere than in South Africa late Siluric or early Devonic tillites are unknown. It is desirable here, however, to direct attention to the supposed tillites mentioned by Ramsay and found in the north of England in the Upper Old Red Sandstone of late Devonic time. Geikie (1903: 1001, 1011) states that this "subangular conglomerate or breccia recalls some glacial deposits of modern time." Jukes-Brown in his book, The Building of the British Isles, 1911, writes of *arid Devonic climates*, but does not mention tillites or glacial climates.

CAMBRIC GLACIATION.

Unmistakable tillites, thought to be of earliest Cambric age, have been described by Howchin and David from southern Australia and by Willis and Blackwelder from China. In both cases the evidence as to age is open to question, as the tillites are either sharply separated from the overlying Cambric deposits or these strata have no fossils to fix their age, thus leading to the inference that the tillites are more probably of late Proterozoic time. In arctic Norway occur other tillites at the base of the thick Gaisa formation. These deposits also were formerly regarded as of Paleozoic age, but Norwegian geologists now refer them to the Proterozoic. All of these tillites are best referred to the vast era previous to the Cambric period.

LATEST PROTEROZOIC GLACIATION.

Australia.—In southern Australia, conformably beneath marine and fossiliferous Lower Cambric strata but sharply separated from them, occur tillites of wide distribution. They extend from 20 miles south of Adelaide to 440 miles north of the same city, with an east-and-west spread of 200 miles. Bowlder clay has also been discovered on the west coast of Tasmania. The tillites range in thickness from about 600 to 1,500 feet and occur at the top of a vast pile of conglomerates, grits, feldspathic quartzites, slates, and phyllites, whose exact age is unknown because as yet no fossils have been discovered in them. (See fig. 3.)

According to Howchin, the tillite consists "mainly of a groundmass of unstratified, indurated mudstone, more or less gritty, and carrying angular, subangular, and rounded bowlders (up to 11 feet in diameter), which are distributed confusedly through the mass. It is in every respect a characteristic till" (1908: 239). The first scratched bowlders were observed in 1901, and now they are known by the "thousands" (David). They range in size up to about 10 feet long. So far no striated underground or glaciated floor has been discovered, and both Howchin and David hold that the tillite was formed at or near sea level in fresh or brackish water with floating icebergs. The rocks of the tills, David thinks, came from the south. The tillite is now found from below sea level to about 1,000 feet above the sea. These tillites and all of the enormous mass of coarse deposits below them, which is at least several miles thick, the Australian geologists regard as of Lower Cambric age, because overlying them occur fossils of this time. The contact between the tillite and the marine Cambric is always a sharp one, leading to the inference that the sea of this time transgressed over an old flat land. Under these circumstances deposition was not continuous, for the geologic section is here broken between the tillite and the Cambric deposits, indicating that the age of the former is rather late Proterozoic than early Paleozoic. From the evidence of the Lower Cambric life, to be presented later, we shall see that the waters of this time, the world over, were of tropical or subtropical temperature, conditions not at all in harmony with the supposed glacial climates of earliest Cambric *time.*

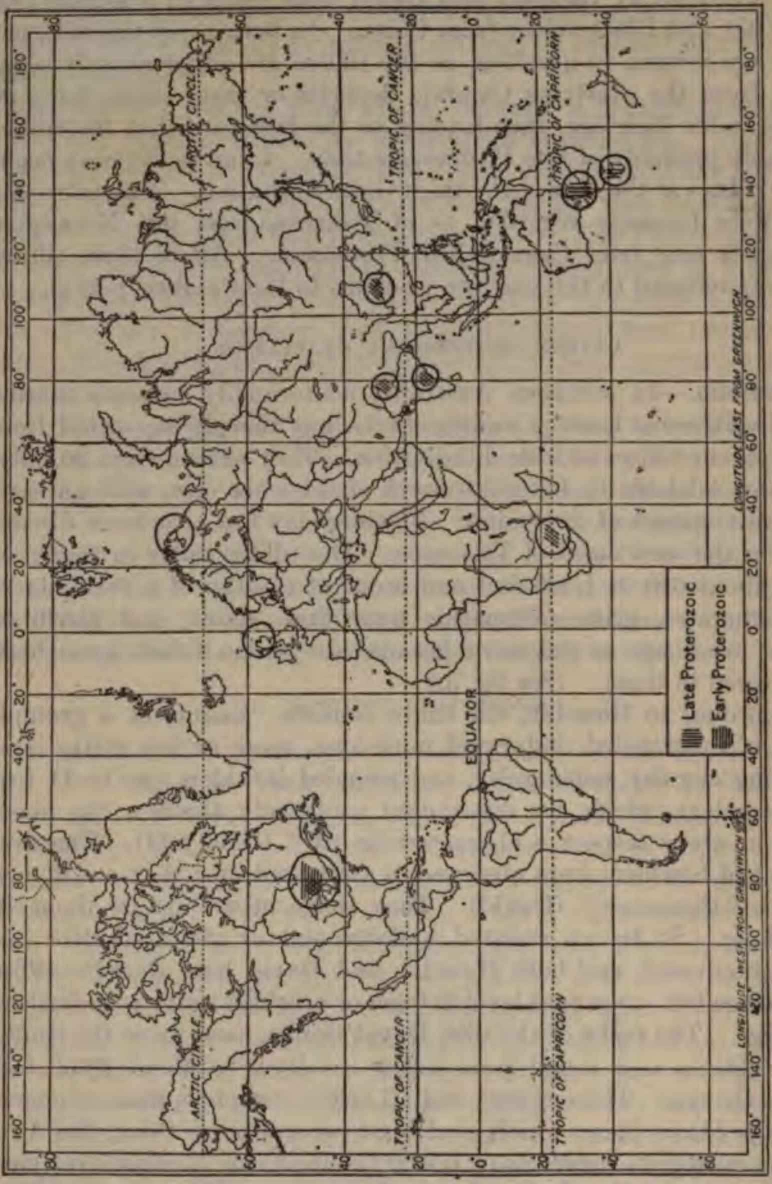

FIG. 3.—Map of Proterozoic glaciation.

The Norwegian occurrence, shown by an empty circle on this map, is supposed to be late Proterozoic, but there is doubt as to the exact date. The occurrence in Great Britain and also the occurrences indicated by diagonal lines are undated Proterozoic.

Arctic Norway.—As long ago as 1891, Dr. Reusch described unmistakable tillites in the Gaisa formation in latitude 70° N. along the Varanger Fiord of arctic Norway. Similar deposits are also known farther east on Kildin Island, and on Kanin Peninsula at Pae. (Ramsay, 1910.) At first the age of these deposits was thought to be late Paleozoic and even Triassic, but the Swedish geologists now correlate the Gaisa with the Sparagmite formation, one of the members of the Seve series. As the latter is overlain by the Lower Cambric fauna, it appears best to refer the Gaisa formation to the top of the Proterozoic series. The tillite occurs at the very base of the Gaisa formation and overlies the ancient and eroded granites. Strahan reinvestigated the area originally studied by Reusch and his description of the geologic phenomena must convince anyone not only that here are intercalated thin zones of sandstone and tillite in a series of red shales (these may indicate warmer and arid interglacial climates), but as well that the tillite rests upon a striated sandstone, the very ground over which the glacier moved. Strahan further states that "the Gaisa Beds, so far as I saw them, do not suggest the immediate neighborhood of a mountain region, for such conglomerates as they contain are neither coarse nor plentiful" (1897:145). Again we have the evidence of tillites formed on low grounds and not in the mountains.

UNDATED PROTEROZOIC GLACIATION.

The following occurrences of tillites do not appear to be of latest Proterozoic time, as do those of Australia and Norway. They are therefore held apart under a separate heading from the tillites of earliest and latest Proterozoic time.

North America.—Prof. Coleman states that "Dr. Bell reports bowlders reaching diameters of 3 feet 8 inches, having grooves like glacial striæ, in a conglomerate with sandy matrix belonging to the Keweenawan of Pointe aux Mines, near the southeast end of Lake Superior. Messrs. Lane and Seaman describe a Lower Keweenawan conglomerate as containing 'a wide variety of pebbles and large bowlders, in structure at times suggestive of till,' from the south shore of Lake Superior" (1908).

India.—In peninsular India occurs the Kadapah system, which, according to Vredenburg, is made up of several series separated from one another by unconformities. The Lower Kadapah is of Proterozoic age and the Upper Kadapah is certainly older than the Siluric and probably even than the Cambric. In the Upper Kadapah occur "remarkable conglomerates or rather bowlder beds consisting of pebbles of various sizes, some of them very large, scattered through a fine-grained slaty or shaly matrix. * * * These peculiar bowlder beds are regarded as glacial in origin" (1907).

In Simla occurs the Blaini formation, also with bowlder beds, the age of which, according to Holland is certainly older than the Permic and possibly of late Proterozoic time. It is "a conglomeratic slate composed of rounded pebbles of quartz, ranging up to the size of a hen's egg, or in other cases angular and subangular fragments of slate and quartzite, of all sizes up to some feet across, which are scattered at intervals through a fine-grained matrix." Holland regards these beds as "almost certainly of glacial origin." They may eventually be shown to be of late Proterozoic age.

Africa.—In Proterozoic strata, far beneath the Table Mountain series, of probably late Siluric or early Devonic age, is the Griquatown or Pretoria series (29° S. lat.), in which glacial materials have been found. At present no definite age in the Proterozoic era can be assigned this formation, nor can it be said that the glacial horizon is either that of the Lower Huronian or of the latest Proterozoic time.

China.—In the Provinces of the middle Yangtse River of China (110° E. long. and 31° N. lat.) Willis and Blackwelder (1907) found resting unconformably upon very ancient granite and gneiss a series of quartzites followed by at least 120 feet of an unmistakable glacial tillite (in places nearly 500 feet thick), green in color, which is in turn overlain by unfossiliferous limestones over 4,000 feet thick. This limestone Willis correlates with the fossiliferous Middle Cambric occurring 100 miles away, and the tillite beneath it is thought to have formed "close to sea level." The age of these tillites is conceded to be at least as old as the Lower Cambric, but when we note that the tillite changes quickly into the overlying limestone within a few feet of thickness, indicating a probable break in sedimentation between the two series of deposits, and the further fact that the overlying limestones have yielded no fossils, we see that these glacial deposits are as yet unplaced in the geologic column. Prof. Iddings restudied these tillites in 1909, and he likewise could find no fossils in the limestone. For the present the tillites are referred to the Proterozoic. What their distribution has been in China is as yet unknown.

Scotland.—In the northwest of Scotland are seen some of the oldest rocks known to the geologists of Europe. The basement formations make up the Lewisian series, comparable to the Laurentian of American geologists. Upon these old gneisses and schists, mainly of igneous origin, reposes unconformably a great pile of dull red sandstones, shales, and conglomerates, referred to as the Torridonian, that Peach states were laid down "under desert or continental conditions" (1912). These attain a thickness of at least 8,000 to 14,000 feet, and are in turn overlain unconformably by Lower Cambric strata having the trilobite Olenellus and related genera. The Torridonian was laid down in part upon a mountainous topography of Lewisian domes strikingly suggestive of glacial erosion.

In western Sutherland and Ross, Giekie states that the observant traveler must be struck by the "extraordinary contour presented by the gneiss. A very slight examination shows that every dome and boss of rock is ice worn. The smoothed, polished, and striated surface left by the ice of the glacial period is everywhere to be recognized. Each hummock of gneiss is a more or less perfect roche moutonnée. Perched blocks are strewn over the ground by thousands. In short, there can hardly be anywhere else in Britain a more thoroughly typical piece of glaciation" (1880).

Over this eroded and smoothed ground was formed a coarse reddish breccia with many of the stones decidedly angular and "sometimes stuck on end in the mass." Some blocks are "fully 5 feet long" but none were found to be scratched or striated. The breccia "is quite comparable to moraine stuff." The material came from a land that lay to the northwest and that has since sunk into the Atlantic.

EARLIEST PROTEROZOIC GLACIATION.

Canada.—The oldest known tillite was recently described by Prof. Coleman. (See fig. 3.) It occurs at the base of the Lower Huronian in the so-called "slate conglomerate," and therefore near the base of the geologic column accessible to geologists. These conglomerates are found "from point to point across all northern Ontario, a distance of nearly 800 miles [now placed at 1,000 miles] and from the north shore of Lake Huron in latitude 46° to Lake Nipigon in latitude 50° [now placed at 750 miles]." "The appearance of these so-called slate or graywacke conglomerates is closely like that of the Dwyka bowlder clays of Africa" (1907). They rest on various formations older than the Huronian, an "undulating surface of low hills and valleys, the conglomerate often more or less filling in these valleys." A scratched or polished underground has been found in three places, but as a rule such are not seen because of the unfavorable conditions for their display. The evidence of the tillites is in favor of the view that glaciation in Huronian Canada was not "the work of merely local mountain glaciers," but rather due to "the presence of ice sheets comparable to those which formed the Dwyka. * * * This implies that the climates of the earlier parts of the world's history were no warmer than those of later times, and that in Lower Huronian times the earth's interior heat was not sufficient to prevent the formation of a great ice sheet in latitude 46°."

CLIMATIC EVIDENCE OF THE SEDIMENTS.

During the past 10 years it has become evident that the color of the delta deposits of geologic time, and especially that of continental deposits, is to be connected largely with differences in climate.

This evidence, however, is as yet difficult of interpretation, because the climatic factors are not easily separated from those due to topographic form. All that can be done now is to call attention to the marked changes in sedimentation from the gray, green, blue, and black colors to the red beds which are so often also associated with coarser materials. Barrell states:

> The changes from the red beds of the Catskill formation, several thousand feet in thickness, to the gray Pocono sandstones with a maximum thickness of 1,200 to 1,300 feet, then to the sharply contrasted red shales and sandstones of the Mauch Chunk, 3,000 feet in maximum thickness, and back to the massive white conglomerates of the Pottsville conglomerate, 1,200 feet in maximum thickness, followed by the coal measures, are all the result of increasingly wide swings of the climatic pendulum which carried the world from Upper Devonian warmth and semiaridity to Upper Carboniferous coolness, humidity, and glaciation (1908).

In regard to the significance of gray to black formations Barrell states:

> Where a whole formation, representing an ancient flood plain or delta, shows in its unweathered portions an absence throughout of the colors due to iron oxide, and a variable presence of carbon, giving grays to black, the inference is that the formation accumulated under a continuously rainy climate or one which in the drier season was sufficiently cool or cold to prevent noteworthy evaporation; such climates as exist in Ireland, Iceland, or western Alaska.

On the other hand, the red colors in stratified rocks are in general due to arid and warm conditions.

> Turning to the climatic significance of red, it would therefore appear both from theoretical considerations and geological observations that the chief condition for the formation of red shales and sandstones is merely the alternation of seasons of warmth and dryness with seasons of flood, by means of which hydration, but especially oxidation of the ferruginous material in the flood-plain deposits is accomplished. * * * The annual wetting, drying, and oxidation not only decompose the original iron minerals, but completely remove all traces of carbon. If this conclusion be correct, red shales or sandstones, as distinct from red mud and sand, may originate under intermittently rainy, subarid, or arid climates without any close relation to temperature and typically as fluvial and pluvial deposits upon the land, though to a limited extent as fluviatile sediments coming to rest upon the bottom of the shallow sea. The origin of such sediment is most favored by climates which are hot and alternately wet and dry as opposed to climates which are either constantly cool or constantly wet or constantly dry.

Red sandstones and sandy shales recur at many horizons in the American Paleozoic strata and markedly so at the close of the Ordovicic, Siluric, Devonic, Lower and Upper Carbonic, and early Permic. The eastern Triassic beds, and those of the Rocky Mountains, are nearly everywhere red throughout, and there is considerable red color in the Lower Cretacic (Morrison and Kootenay) of the Great Plains area. Then, too, there are many red beds in the Proterozoic of America as well as of Europe. Between these zones of brilliant strata are the far more widely distributed ones of grays and darker colors, and these are the deposits of the times when the oceans have most widely transgressed the lands, and therefore the times of greater humidity. The maximum of continental extension falls in with red deposits and more or less arid climates. (See curve for aridity in fig. 4, p. 305.)

VOLCANIC DUST AS A CLIMATIC FACTOR.

Two interesting papers on the subject of volcanic dust as a climatic factor have recently appeared. These articles, which are by W. J. Humphreys,[1] should be read by every student of paleometeorology. The following are the conclusions reached:

> [Volcanic dust in the upper atmosphere has been one of] several contributing causes of climatic change, * * * a cause that during historic times has often been fitfully operative, and concerning which we have much definite information. * * *
>
> At an elevation that in middle latitudes averages about 11 kilometers the temperature of the atmosphere becomes substantially constant, or, in general, ceases appreciably to decrease with increase of elevation, this is, therefore, the upper limit of distinct vertical convection and of cloud formation. Hence, while volcanic or other dust in the lower or cloud region of the atmosphere is quickly washed out by snow or rain, that which by any process happens to get into the upper or isothermal region must continue to drift there until gravity can bring it down to the level of passing storms. In other words, while the lower atmosphere is quickly cleared of any given supply of dust, the isothermal region retains such dust as it may have for a time that depends upon the size and density of the individual dust particles themselves, or upon the rate of fall. * * * Volcanic dust once in the upper atmosphere must remain in it for many months and be drifted out, from whatever origin, into a thin veil covering perhaps the entire earth. * * * A veil of volcanic dust must produce an inverse greenhouse effect, and if long continued, should perceptibly lower our average temperature. Let us see then what observational evidence we have on the effect of volcanic dust on insolation intensity and average temperatures.
>
> Pyrheliometric records [show] that there was a marked decrease in the insolation intensity from the latter part of 1883 (the year this kind of observation was begun) to and including 1886, from 1888 to 1892, and during 1903. There has also been a similar decrease since about the middle of 1912. Now all these decreases of insolation intensity, amounting at times to 20 per cent of the average intensity, followed violent volcanic eruptions that filled the isothermal region with a great quantity of dust. * * *
>
> It appears quite certain that volcanic dust can lower the average temperature of the earth by an amount that depends upon the quantity and duration of the dust, and that it repeatedly has lowered it certainly from 1° F. to 2° F. for periods of from a few months to fully three years. Hence it certainly has been a factor, in determining our past climates, and presumably may often be a factor in the production of our future climates. Nor does it require any great volume of dust to produce a marked effect. Thus it can be shown by a simple calculation that less than the one-thousandth part of a cubic mile of rock spread uniformly through the upper atmosphere as volcanic dust would everywhere decrease the average intensity of insolation received at the surface of the earth by at least 20 per cent and therefore would, presumably, if long continued, decrease our average temperatures by several degrees. * * * This

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[1] A summary paper appeared first, entitled "Volcanic dust as a factor in the production of climatic changes," Jour. Washington Acad. Sci., 3, 1913: 365-371. The complete article is "Volcanic dust and other factors in the production of climatic changes, and their possible relation to ice ages," Bull. Mt. Weather Observ., Washington, 6, Pt. I, 1913, 1-34.

effect has been clearly traced back to 1750, or to the time of the earliest reliable records. Hence it is safe to say that such a relation between volcanic dust in the upper atmosphere and average temperatures of the lower atmosphere has always obtained and therefore that volcanic dust must have been a factor, possibly a very important one, in the production of many, perhaps all, past climatic changes.

The intensity of the solar radiation at the surface of the earth depends upon not only the dustiness of the earth's atmosphere but also upon the dustiness, and of course the temperature, of the solar atmosphere. Obviously dust in the sun's envelope must more or less shut in solar radiation just as and in the same manner that dust in the earth's envelope shuts it out. Hence it follows that when this dust is greatest, other things being equal, the output of solar energy will be least, and that when the dust is least, other things being equal, the output of energy will be greatest. Not only may the intensity of the emitted radiation vary because of changes in the transparency of the solar atmosphere but also because of any variations in the temperature of the effective solar surface which, it would seem, might well be hottest when most agitated, or at the times of spot maxima, and coolest when most quiescent, or at the times of spot minima.

BIOLOGIC EVIDENCE.

In the previous pages there has been presented the evidence for cold climates during geologic times as furnished by the presence of the various tillites. This presentation has also been made from the standpoint of discovery of the tillites, which in general is in harmony with geologic chronology, i. e., the youngest tillites were the first to be observed, while the most ancient one has been discovered recently.

Variability of climate is also to be observed in the succession of plants and animals as recorded in the fossils of the sedimentary rocks. In this study we are guided by the distribution of living organisms and the postulate that temperature conditions have always operated very much as they do now upon the living things of the land and waters. In presenting this biologic evidence we shall, however, begin at the beginning of geologic time and trace it to modern days, for the reason that life has constantly varied and evolved from the more simple to the more complex organisms.

Proterozoic.—The first era known to us with sedimentary formations that are not greatly altered is the Proterozoic, a time of enormous duration, so long indeed that some geologists do not hesitate to say that it endured as long as all subsequent time. These rocks are best known and occur most extensively over the southern half of the great area of 2,000,000 square miles covered by the Canadian shield. There were at least four cycles of rock making, each one of which, in the area just north of the Great Lakes and the St. Lawrence River, was separated from the next by a period of mountain making. These mountains were domed or batholithic masses of vertical uplift due to vast bodies of deep-seated granitic magmas rising beneath and into the sediments. In the Grenville area of Canada, Adams and Barlow (1910) tell us that the total thickness of the pre-Proterozoic rocks alone is 94,406 feet, or nearly 18 miles. Of this vast mass more than half (50,286 feet) is either pure limestone, magnesian limestone, or dolomite, and single beds are known with a thickness of 1,500 feet. Certainly so much limestone represents not only a vast duration of time but also warm waters teeming with life, almost nothing of which is as yet known. There is further evidence of life in the widely distributed graphites, carbon derived from plants and animals, which make up from 3 to 10 per cent by weight of the rocks of the Adirondacks. (Bastin, 1910.) The graphite occurs in beds up to 13 feet thick, and at Olonetz, Finland, there is an anthracite bed 7 feet thick.

It is also becoming plain that there was in the Proterozoic a very great amount of fresh-water and subaerial deposits, the so-called continental deposits, some of which indicate arid climates. Because of the apparent dominance of continental deposits and the great scarcity of organic remains throughout the Proterozoic, Walcott has called this time the Lipalian era (1910).

We have seen that the Proterozoic began with a glacial period, as evidenced by the tillites of Canada, but that this frigid condition did not last long is attested by the younger Lower Huronian limestones of Steeprock Lake, Ontario, having a thickness of from 500 to 700 feet and replete with Atikokania, sponges up to 15 inches in diameter, and forming reef limestones several feet thick, found there by Lawson and described by Walcott (1912). This discovery is of the greatest value, and opens out a new field for paleontologic endeavor in Proterozoic strata and for philosophic speculation as to the time and conditions when life originated.

We have also seen that the Proterozoic closed with a frigid climate, as is attested by the tillites of Australia, Tasmania, and possibly China, while the other glacial deposits of India, Africa, Norway, and Keweenaw certainly do in part indicate another and older period of cool to cold world climates.

Cambric.—Due to the researches of many paleontologists, but mainly to those of Charles D. Walcott, we now know that the shallow-water seas of Lower Cambric time abounded in a varied animal life that was fairly uniform the world over in its faunal development. It was essentially a world of medusæ, annelids, trilobites, and brachiopods, animals either devoid of skeletons or having thin and nitrogenous external skeletons with a limited amount of lime salts. The "lime habit" came in dominantly much later; in fact, not before the Upper Cambric. However, that the seas in Lower Cambric time had an abundance of usable lime salts in solution is attested by the presence of many Hyolithes, small gastropods and brachiopods, and more especially by the great number of Archæocyathinæ, most primitive corals, which made reefs and limestones 200 feet thick and of wide distribution in Australia, Antarctica, California (thick limestones near the base of the Waucoba section), southern Labrador (reefs 50 feet thick), and to a smaller extent in Nevada, New York, Spain, Sardinia, northern Scotland, and arctic Siberia.

With an abundance of limestone and reef-making animals of worldwide distribution in the Lower Cambric, we must conclude that the climate at the time was at least warm and fairly uniform in temperature the world over. We therefore see the force of a statement made to the writer by Walcott some years ago in a letter that "the Lower Cambrian fauna and sediments were those of a relatively mild climate uninfluenced by any considerable extent of glacial conditions," and also that "the glacial climate of late Proterozoic time had vanished before the appearance of earliest Cambrian time."

Toward the close of Lower Cambric time there was considerable mountain making, without apparent volcanic activity, going on all along eastern North America and to a lesser extent in western Europe. These uplifts seemingly had much effect upon the marine life, for the Middle Cambric faunas became more and more provincial in character in comparison with the earlier, more cosmopolitan faunas of Lower Cambric time.

The Archæocyathinæ now vanished, and their extinction is suggestive of cooler waters; there was, however, a greater variety of invertebrate forms, more lime-secreting invertebrates, and far more widespread limestone deposition in Middle Cambric time. In the Upper Cambric the brachiopods, gastropods, cephalopods, and bivalve crustaceans were abundantly represented by thick-shelled forms, and in most places throughout North America there was marked deposition of limestones, magnesian limestones, and dolomites, all of which is suggestive of warmer waters.

Ordovicic and Siluric.—The Ordovicic seas from Texas far into the arctic regions were dominated by limestone deposits and a great profusion of marine life that was also more highly varied than that of any earlier time. The same species of graptolites, brachiopods, bryozoans, trilobites, and other invertebrate classes had a very wide distribution, all of which is evidence that at that time the earth had mild and uniform climates. In the Middle Ordovicic and again late in that period reef corals were common from Alaska to Oklahoma and Texas.

Toward the close of the Ordovicic mountain making was again in progress throughout eastern North America without significant volcanic activity, but in western Europe, where the movements were less marked, volcanoes were more plentiful. The seas were then almost completely withdrawn from the continents, and yet when the Siluric waters again transgressed the lands we find not only the same great profusion and variety of life as before, but as widely extended limestone deposition. The evidence is again that of mild and uniform climates. We can therefore say that the temperatures of air and water had been mild to warm throughout the world since the beginning of Cambric time, that there was a marked increase of warmth in the Upper Cambric, and that these conditions were maintained throughout the Ordovicic and the earlier half of the Siluric, since shallow-water corals, reef limestones, and very thick dolomites of Siluric time are as common in arctic America as in the lower latitudes of the United States or Europe.

The Siluric closed with an epoch of sea withdrawal and North America was again arid, for now red shales, gypsum, thick beds of salt, and great flats of sun-cracked water limestone were the dominant deposits of the vanishing seas. The marine faunas were as a rule scant and the individuals generally under the average size. In North America no marked mountain making was in progress, but all along western Europe, from Ireland and Scotland across Norway into far Spitzbergen, the Caledonian Mountains were rising. In eastern and northern Maine throughout Middle and Upper Siluric time there were active volcanoes of the explosive type, for here occur vast deposits of ash.

Devonic.—In the succeeding Lower Devonic time the Caledonian intermontane valleys of Scotland and north to at least southern Norway were filling with the Old Red sandstone deposits of a more or less arid climate. On the other hand, the invading seas of northern Europe were small indeed, and their deposits essentially sandstones or sandy shales, but in southern Europe and North America, where the invasions were also small and restricted to the margin of the continent, the deposits were either limestones or calcareous shales. The life of these waters was quite different from that of the earlier and Middle Siluric, and entire stocks had been blotted out in later Siluric time, as is seen best among the graptolites, crinids, brachiopods, and trilobites, while new ones appeared, as the goniatites, dipnoans or lung fishes, sharks, and the terrible armored marine lung fishes, the arthrodires.

From this evidence we may conclude that the early Paleozoic mild climates were considerably reduced in temperature toward the close of the Siluric and that even local glaciation may have been present. Refrigeration may have been greatest in the Southern Hemisphere, where the marine formations of Devonic time are coarse in character and, in Africa, of very limited extent. Corals were scarce or absent here, and in South Africa the glacial deposits of the Table Mountain series may be of late Siluric age; if so, they harmonize with the Caledonian period of mountain making in the Northern Hemisphere. Warmer conditions again prevailed in the latter hemisphere early in Middle Devonic times, for coral reefs, limestones, and a highly varied marine life with pteropod accumulations were of wide distribution.

On Bear Island workable coal beds were laid down in late Devonic time.

Throughout the Devonic, but more especially in the Lower and Middle Devonic, the entire area of the New England States and the maritime provinces of Canada was in the throes of mountain making, combined with a great deal of volcanic activity. At the same time, many volcanoes were active throughout western Europe.

Carbonic.—The world-wide warm-water condition of the late Devonic seas of the Northern Hemisphere was continued into those of the Lower Carbonic. These latter seas were also replete with a varied marine life, among which the corals, crinids, blastids, echinids, bryozoans, brachiopods, and primitive sharks played the important rôles. Limestones were abundant and with the corals extended from the United States into arctic Alaska. Reefs of Syringopora are reported in northern Finland at 67° 55′ N., 46° 30′ E., on Kanin Peninsula (Ramsay). Even several superposed coal beds, and up to 4 feet in thickness of pure coal, of early Lower Carbonic age, occur at Cape Lisburne, overlain by Lower Carbonic limestones with corals. It is generally held that the world climate at this time was uniformly mild and the many hundred kinds of primitive sharks lead to the same conclusion. There were in the American Devonic 39 species of these sharks, in the Lower Carbonic not less than 288, in the Coal Measures 55, and in the earliest Permic only 10. They had no enemies other than their own kind to fear, and as the same rise and decline occurred also in Europe, we must ask ourselves what was the cause for this rapid dying out of the ancient sharks during and shortly after early Coal Measures time. With the sharks also vanished most of the crinids, but otherwise there was an abundance and variety of marine life (wide distribution of large foraminifers) with much limestone formation. The vanishing of the sharks does not appear therefore to have been due solely to a reduction of temperature, but may have been further helped by the oscillatory condition and retreat of the late Lower Carbonic seas.

Toward the close of the Lower Carbonic, or after the Culm and its coals of western Europe had been laid down, mountain movements on a great scale began to take place in central Europe, and then were born the Paleozoic Alps of that continent. These mountains, Kayser tells us, were in constant motion but with decreasing intensity throughout the Upper Carbonic, culminating in "a mighty chain of folded mountains." Toward the close of the Upper Carbonic began the rise of the Urals, which was finished in late Permic time when the Paleozoic Alps of Europe were again in motion. These movements are also traceable in Armenia and others are known in central and eastern Asia. Likewise, in America, the southern Appalachians were in movement at the close of the Lower Carbonic, but the greatest of all of the Upper Carbonic thrustings began to take place at the close of the period and culminated apparently in the earlier half of Permic time, when the entire Appalachian system from Newfoundland to Alabama, and the Ouachita Mountains, extending through Arkansas and Oklahoma, arose as majestic ranges anywhere from 3 to 4 miles high.

These mountain-making movements of long duration at first caused the oceans to oscillate frequently back and forth over parts of the continents, and great brackish-water marshes were developed, producing the greatest marsh floras and the greatest accumulations of good coals that the world has had. The paleobotanists White and Knowlton tell us that the climate of Upper Carbonic time was relatively uniform and mild, even subtropical in places, accompanied by high humidity extending to or into the polar circles. Plant associations were then "able to pass from one high latitude to the opposite without meeting an efficient climatic obstruction in the equatorial region" (1910).

The marine faunas of Upper Carbonic time were fairly uniform in development, and many species had a wide distribution, although the biotas were still somewhat provincial in character. Limestones or calcareous shales predominated. The large Protozoa of the family Fusulinidæ occurred throughout the Northern Hemisphere and less widely in South America. They were also very common in Spitzbergen. Staff and Wedekind (1910) state that the Fusulinidæ occur here in a black asphaltic calcareous rock, i. e., a sapropel like those now forming in marine tropical regions, according to Potonié. The water, they state, was shallow, highly charged with calcium carbonate and of a tropical character, or at the very least not cooler than that of the present Mediterranean. The very large insects of the Coal Measures tell the same climatic story, for Handlirsch (1908) says that the cockroaches of that time were as long as a finger and the libellids as long as an arm. They were "brutal robbers" and scavengers living in a tropical and subtropical climate, or at the very least in a mild climate devoid of frosts. We therefore conclude that after Middle Devonic time the climate of the world was as a rule uniformly warm and more or less humid and that it remained so to the close of Upper Carbonic time.

During the time of these mild and humid climates vast accumulations of carbon extracted by the plants out of the atmosphere were being stored up in brackish and fresh water swamps, and even greater quantities of this element were being locked up in the limestones and calcareous shales in the seas and oceans. According to the physicochemist Arrhenius and many geologists and paleontologists, so much loss of carbon dioxide and its associated water vapor from the air must have thinned the latter greatly and thus largely reduced the atmospheric blanket and retainer of the sun's heat rays. Therefore they hold that these factors alone were sufficient to have brought on a glacial climate. It may be that this theory will not stand the test of time, but even so we have learned that in Carbonic times there were earth movements on so grand a scale as to be but slightly inferior to those of the late Tertiary that were followed by the Pleistocene glacial climate.

Permic.—Very early in Permic time the mild climate of the past was greatly changed; the evidence is now overwhelming that throughout the Southern Hemisphere there was a glacial period seemingly of even greater extent than that of the Northern Hemisphere during the Pleistocene. This evidence is most easily seen in the wide distribution of the tillites and the scratched and polished grounds over which the land ice moved in Africa, Australia, Tasmania, India, and South America. In the Northern Hemisphere the evidence of ice work is far less marked; but tillites occur near Boston, Massachusetts, and in the Urals, and there is much evidence of thin and arid climates, seen in the widely distributed red formations. Then, too, the land life of this time clearly indicates that a great climatic change had taken place in the environment of the organic world.

The grand cosmopolitan swamp floras of the Upper Carbonic, consisting in the main of spore-bearing plants, such as the rushes (Equisetales), the running pines, and clubmosses (Lycopodiales), and the ferns, among which were also many broad-leaved evergreens (Cordaitales) and seed-bearing ferns (Cycadofilicales), were very largely exterminated in the Southern Hemisphere at the beginning of Permic time. In the Northern Hemisphere, however, the older flora maintained itself for a while longer, as best seen in North America, but finally the full effects of the cooled and glacial climates were felt everywhere. Then in later Permic time the old floras completely vanished, except the hardier pecopterids, cycads, and conifers of the Northern Hemisphere, and with these latter mingled the migrants from the hardy Gangamopteris flora originating in the glacial climate of the Southern Hemisphere. (White, 1907.) Some of the trees show distinct annual growth rings, and hence the presence of winters. It was these woody floras that gave rise to the cosmopolitan floras of early Mesozoic time.

With the vanishing of the cosmopolitan coal floras also went nearly all of the Paleozoic insect world of large size and direct development, for the insects of late Permic time were small and prophetic of modern forms. Then, too, they all passed through a metamorphic stage indicating, according to Handlirsch, that the insects of earlier Permic time had learned how to hibernate through the winters in the newly originated larval conditions.

Our knowledge of the land vertebrates of late Paleozoic time is increasing rapidly, and it is becoming plainer that great changes were also in progress here. The vertebrates of the Coal Measures, either the armored amphibians (Stegocephalia) or the primitive reptiles, were still largely addicted to the "water habit" and lived in fresh waters or swamps, but this was much changed by the arid climates and vanishing swamps of later Permic times, and in the Triassic we meet with the first truly terrestrial reptilian faunas.

A climatic change naturally must affect the land life more quickly and profoundly than that of the marine waters, for the oceanic areas have stored in themselves a vast amount of warmth that is carried everywhere by the currents. The temperature of the ocean is more or less altered by the changes of climate, be they of latitude or of glaciation. The surface temperatures in the temperate and tropical regions, however, are the last to be affected, and only change when all of the oceanic deeps have been filled with the sinking cold waters brought there by the currents flowing from the glaciated area. We therefore find that the marine life of earlier Permic time was very much like that of the Coal Measures, and that it was not profoundly altered even in the temperate zones of Middle Permic time (Zechstein and Salt Range faunas). Our knowledge of Upper Permic marine life is as yet very limited and will probably always remain so because of the world-wide subtraction of the seas from the lands at that time. It was a period of continued arid climates, and the marginal shallow sea pans were, as a rule, depositing red formations with gypsum, and locally, as in northern Germany, alternations of salt with anhydrite or polyhalite in thicknesses up to 3,395 feet. In certain of these zones there were developed annual rings so regular in sequence as to lead to the inference that they were the depositions of warm summers and cold winters, enduring for at least 5,653 years. (Görgey, 1911.)

Triassic.—When we examine into the Triassic faunas we meet at once with a wholly new marine assemblage. The late Paleozoic world of fusulinids, tetracorals, crinids, brachiopods, nautilids, and trilobites had either vanished or was represented by a few small and rare forms. On the other side, in the Triassic, their places were taken by a rising marine world of small invertebrates, now hexacorals, regular echinids, modern bivalves (among them the oysters), siphonate gastropods, and more especially by a host of ammonites and a prophecy of the coming of squids and marine reptiles. Truly, there is no greater change recorded in all historical geology.

Plants are scarce in the rocks of Triassic time until near its close in the Rhætic, when we can again truly speak of Triassic floras. These are known from many parts of the world, and according to Knowlton there is nothing in the floras to suggest a "depauperate and pinched" condition, as has often been said. "In North Carolina, Virginia, and Arizona there are trunks of trees preserved some of which are 8 feet in diameter and at least 120 feet long, while hundreds are from 2 to 4 feet in diameter. Many of the ferns (some are tree ferns) are of large size, indicating luxuriant growth, while Equisetum stems 4 to 5 inches in diameter are only approached by a single living South American species. * * * The complete or nearly complete absence of rings in the tree trunks indicates that there were no, or but slight, seasonal changes due to alternations of hot and cold or wet and dry periods." On the whole, the climate was "warm, probably at least subtropical" (1910).

Of insects, too few species (27) are known to be of value for climatic deductions. On the other hand, the reptilian life of the Triassic in America, Africa, and Europe was highly varied, and with the dinosaurs dominant and often of large size again gives evidence that appears to be indicative of uniform and mild climate.

The marine Triassic deposits consisted largely of thick limestones, and such are well developed in arctic America and arctic Siberia. One of the oldest faunas, known as the Meekoceras fauna, has a very great distribution from Spitzbergen to India and Madagascar, and from Siberia at Vladivostok to California and Idaho. In general, however, the Triassic assemblages were more provincial, and it was not until middle and late Triassic time that the faunas again had wide distribution. Limestones with thick coral reefs, of the same age, appear in the Alps (up to 1,000 meters thick), India, California, Nevada, Oregon, and arctic Alaska. Smith, from whom most of these facts were taken, states that this shows there was during the Triassic "nearly uniform distribution of warm water over a great part of the globe" (1912).

We may therefore conclude that the rigid climate of the Permic had vanished even before the earliest of Triassic times, and that the climate of the latter period until near its close was again mild and fairly uniform though semiarid or even arid the world over.

Late Triassic-Lias.—Throughout much of late Triassic time there was renewed crustal instability, for we have the evidence of volcanism on a great scale all along the Pacific from central California into far Alaska, in eastern North America from Nova Scotia to Virginia, in Mexico, South America (in southern Brazil 600 meters thick), and New Zealand. The volcanoes of western North America were probably insular in position, for their lavas and ash beds are found interbedded with marine sediments. Just how important this movement was and what effect it had upon the climate is not yet clear, but there is important organic evidence leading to the belief that the temperature was considerably reduced during latest Triassic and earliest Jurassic time.

Pompeckj, Buckman, and Smith state that late Triassic time was a particularly critical one for the ammonites. Of the far more than 1,000 known species of Triassic ammonites, not one passed over into the Jurassic, and but a single family survived this time, the Phylloceratidæ. Pompeckj says that "out of Phylloceras has developed the abundance of Jurassic-Cretaceous ammonites" (1910), while Buckman holds it was out of Nannites by way of the Liassic Cymbites that the later fullness of ammonite development came.

In the Liassic there are now known 415 species of insects that remind one much of modern forms. Nearly all were dwarf species, smaller than similar living insects of the same latitude and far smaller than Paleozoic or Upper Jurassic insects. Handlirsch (1910) is positive that this uniform dwarfing of the Liassic insects was due to a general reduction of the climate and that the temperature was then cool and like that of present northern Europe between latitudes 46° and 55°. The climate, he states, was certainly cooler than either that of the Middle Triassic or Upper Jurassic.

In this connection we must not overlook the fact that the known Liassic insects are of wide distribution, for 172 species are known from England, 164 from Mecklenburg, northern Germany, 75 from Switzerland, and 2 from upper Austria. With this depauperating of the insects and the vanishing of the late Triassic ammonites, there is also to be noted a marked quantitative reduction and geographic restriction among the reef corals of Liassic time. We therefore are seemingly warranted in concluding that the cooling of the climate in late Triassic and early Jurassic time was not local in character, but was rather of a general nature. Much workable coal was also laid down in Liassic time, not only in Hungary but also in many places eastward into China and Japan. In addition, the many black shales of this time furnished further evidence of cool and nontropical climates; coal and black shales are so general in occurrence throughout the Liassic rocks that the time is often referred to as the Black Jura. Finally, certain Liassic conglomerates of Scotland have been thought by some to be of glacial origin. (J. Geikie.)

Jurassic.—The Jurassic formations of Europe are so rich in fossils that they have been the classic ground on which many paleontologists and stratigraphers were reared. From the studies of these faunas came the first clear ideas of climatic zones and world paleogeographic maps through the work of the great Neumayr of Vienna. As the result of a very long study of the ammonites and their geographic distribution, he came to the conclusion in 1883 that the earth in Jurassic time had clearly marked equatorial, temperate, and cool polar climates, agreeing in the main with the present occurrence of the same zones. He also said that "the equator and poles could not have very much altered their present position since Jurassic times." His conclusions were, however, assailed by many, and while no one has greatly altered his geographic belts of ammonite distribution, still the consensus of opinion to-day is that these are representative rather of faunal realms than of temperature belts. On the other hand, it is admitted that there were then clearly marked temperature zones; that is, a very wide medial warm-water area, embracing the present equatorial and temperate zones, with cooler but not cold water in the polar areas. That the oceanic waters of Middle and (somewhat less so) of Upper Jurassic times were warm throughout the greater part of the world is seen not only in the very great abundance of marine life—probably not less than 15,000 species are known in the Jurassic—but also in the far northern distribution of many ammonites, reef corals, and marine saurians. The Jurassic often abounds in reefs made by sponges, corals, and bryozoans. Jurassic corals occur 3,000 miles north of their present habitats.

The Jurassic floras were truly cosmopolitan, and Knowlton tells us that of the North American species, excluding the cycad trunks, about half are also found in Japan, Manchuria, Siberia, Spitzbergen, Scandinavia, or England. "What is even more remarkable, the plants found in Louis Philippe Land, 63° S., are practically the same [both generically and specifically] as those of Yorkshire, England. * * * The presence of luxuriant ferns, many of them tree ferns, equisetums of large size, conifers, the descendants of which are now found in southern lands, all point to a moist, warm, probably subtropical climate" (1910). The insects of this time were again large and abundant, indicating a warm climate—evidence in harmony with the plants.

At the close of the Jurassic the Sierra Nevadas of California and the Humboldt Ranges of Nevada were elevated; probably also the Cascade and Klamath Mountains farther north; but this disturbance seemingly had no marked effect upon the world's climate, though there was a considerable retreat of the seas from the continents.

Cretacic.—The emergence of the continents at the close of the Upper Jurassic gave rise to extensive accumulations of fresh-water deposits, known in western Europe as the Wealden, and in the Rocky Mountain area of North America as the Morrison. These are now regarded as of Lower Cretacic (more accurately Comanchic) age. Along the Atlantic border of the United States occur other continental deposits, known as the Potomac formations, in the upper part of which the modern floras or Angiosperms make their first appearance. Before the close of the Lower Cretacic this early hardwood forest had spread to Alaska and Greenland, where elms, oaks, maples, and magnolias occurred. Knowlton concludes from this evidence that the climate "was certainly much milder than at the *present* time" and "was at least what we would now call warm temperate" (1910). It was therefore a climate somewhat cooler than that of the Jurassic. On the other hand, the Neocomian series of King Karl's Land has silicified wood, the trunks of which, according to Nathorst, are at least 80 centimeters in diameter and show 210 annular rings. These rings are far better developed than in stems of the same age found in Europe, " which indicates that the trees lived in a region where the difference between the seasons was extremely pronounced" (1912).

During Comanchic time, in the temperate and tropical belts, the world had the greatest of all land animals, the dinosaurs, reptiles attaining a length in North America of 75 feet or more and in equatorial German East Africa of probably more than 100 feet. Their bones range to 50° North latitude, and the animals must have lived in a fairly warm and moist climate.

While the Lower Cretacic seas were prolific in life, the most characteristic shellfish of southern Europe, the Mediterranean countries, and Mexico were the limestone-making rudistids, large ground-living foraminifers (Orbitolina), and reef corals. In northern Europe and in the United States from southern Texas to Kansas nothing of these warm-water faunal elements is known. It is recognized that the north European seas had Arctic connections by way of Scandinavia and Russia, and along the west coast of North America are seen many other boreal migrants as far south as California and even Mexico. These waters, however, were not cold. The same geographic distribution prevailed in the Upper Cretacic of Europe. This distribution was first noted in Texas by Ferdinand Roemer in 1852, and he further observed that "in each case the European deposit is approximately 10° farther north than its American analogue," and concluded, "that the differences between the northern and southern facies were due to climate and that the climatic relations between the two sides of the Atlantic were about the same in Cretaceous time as they are now." (Stanton, 1910.) Even though Roemer's conclusion as to climatic zones was founded on erroneous stratigraphic correlations, still his theory has long been looked upon favorably, but in 1908 Gothan showed that the fossil woods of the late Upper Cretacic of central Germany have distinct annual rings, while those of Egypt do not have a trace of them. The late Cretacic woods of Spitzbergen also have decided growth rings. Berry (1912) states that the climate of Upper Cretacic time was far more uniform than now and that there was an increase of warmth southward, Alabama having then a climate that was subtropical or even tropical. On the other hand, the early Upper Cretacic or Cenomanian flora of Atane in western Greenland, according to Nathorst, "is particularly rich in the leaves of Dicotyledonous trees, among which are found those of planes, tulip trees, and bread fruits, the last mentioned closely resembling those of the bread-fruit tree (*Artocarpus incisa*) of the islands of the southern seas" (1912).

In Middle Cretacic times the oceans began again to spread over the continents and this transgression of the seas was one of the greatest of the geologic past. It is interesting to note that even though there was great opportunity for expansive evolution, but few new marine stocks appeared here, and it was rather a time of death to many characteristic stocks. This well-known fact is clearly brought out by Walther in his interesting book, "Geschichte der Erde und des Lebens" (1908), in chapter 26, entitled "Cretaceous time and its great mortality." Entire stocks of specialized forms vanished, just as did other stocks at the close of the Paleozoic. In late Cretacic time it was the ammonites, belemnites, the rudistids that began to develop in great numbers in the Lower Cretacic, and the other thick-shelled large bivalves (Inoceramus) that perished. In addition, there was a great reduction among the reef corals, the replacing of the dominant ganoids by the teleosts or bony fishes, and, finally, the complete dying out of the various stocks of marine saurians.

On the land, with the further rise of the Angiosperm floras, we see the vanishing of the reptilian dragons known as pterodactyls, and, at the very close of the Cretacic, the last of the large and small dinosaurs and the birds with teeth. "We thus see the reptiles displaced from the seas by the fishes; on the land they are restricted by the rise of the mammals, in the air after a short struggle by the more finely organized birds—in short, the reptilian dominance is destroyed with the end of the Mesozoic era, in which entire time they were the characteristic feature." (Koken, 1893.)

The Upper Cretacic was therefore a time of great mortality among animals, "here sooner, there later; although numerous relict faunas are preserved for a time and last into the Cenozoic, still there never was so great a mortality as that taking place toward the close of the Cretacic." (Walther, 1908.)

During the Upper Cretacic, but more especially toward the close of the period, mountain making on a vast scale went on, along with exceptional outpourings of lavas and ashes. These movements, though of less intensity, were repeated in early Tertiary times, and while they were equaled only by those of the closing period of the Paleozoic, they were exceeded by the crustal deformation of late Tertiary time; they form the Laramide revolution of Dana, embracing the mountains of western North and South America from Cape Horn to Alaska and the reelevation of the Appalachian and Antillean Mountains. Throughout the Eocene in the Rocky Mountains there were many volcanoes throwing out immense quantities of ashes in which is entombed a remarkable vertebrate fauna. Then in late Cretacic time in peninsular India occurred the Deccan lava flows, the most stupendous eruptions known to geologists, covering an area of 200,000 square miles, in thickness anywhere up to a mile or more.

Although there were these great crustal movements toward the close of the Upper Cretacic, nevertheless they seem to have had no marked effect on the climates of the world, for nowhere has anyone shown the presence of unmistakable glacial tills of this age.[1] Then, too, the floras of early Tertiary times are said to be of about the same character as those of the late Cretacic, and they indicate that the climates were warm with slight latitudinal variation, so slight that even in Greenland and Spitzbergen the early Tertiary floras were those of a moist and mild climate.

Tertiary.—We have seen that there was no marked climatic change in the time from the Cretacic to the Eocene, but that there was a reduction in temperature is admitted by paleobotanists and students of marine life. Berry states that the Middle Eocene floras of Europe "show many tropical characters absent in the earlier Eocene" (1910). The Oligocene marine faunas were prolific in species, and the largest of all foraminifers, the nummulites, although still present at this time, had their widest distribution and largest species in the Middle Eocene and especially in the Tethyian Sea of the Old World, extending from 20° South to 20° North latitude. (Stromer, 1909.)

In Miocene time on Spitzbergen (Cape Staratschin) lived the swamp cypress (*Taxodium distichum miocenum*), a leafy sequoia, pines and firs, besides various hardwood trees, such as poplars, birches, beeches, oaks, elms, magnolias, limes, and maples. The swamp cypress, Nathorst says, "formed forests, as in the swamps in the southern portion of the United States. This conclusion is also confirmed by the occurrence of the remains of rather numerous insects" (1912). All of the plants mentioned then flourished as far north as 79° North latitude, and even at nearly 82° in Grinnell Land. This is evidence that in early Miocene time the climate was at least warm-temperate in arctic America.

Again, Dall (1895) states that in Middle Miocene time considerable reduction of the climate appeared, for the Atlantic Chesapeake faunas were those of temperate waters and they spread southward as far as the eastern area of the Gulf of Mexico. Similar conditions are noted by the same conchologist in the northern Pacific Ocean.

The Tertiary was an era of extraordinary crustal movements, finally resulting in the greatest mountain chains of all geologic time. These movements began in early Eocene time in the Rocky Mountains and at the close of this epoch further deformation took place in the Klamath and Coast Ranges of Oregon and the Santa Cruz Mountains of California. In Europe the elevations of Tertiary time started at the close of the Eocene in the Pyrenees, and in the Miocene the entire "Alpine system" was in elevation. This unrest spread at the same time to the Caucasus, Asia, and to the entire Himalayan region of highest mountains and elevated plateaus, an area 22° of latitude in width. It is probable that all of the world's great mountain chains were more or less reelevated in Miocene and Pliocene times, resulting in the present abnormally high stand of the continents when contrasted with the oceanic mean level.

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[1] At the Princeton meeting of the Geological Society of America, Dec. 29, 1913, Prof. W. W. Atwood announced the discovery of a tillite about 90 feet thick in the San Juan Mountains of southwestern Colorado. The age of these glacial deposits is somewhere between late Cretacic and late Eocene. We therefore are now on the road to finding the physical evidence of a reduced climate during or following the close of the Laramide revolution.

These elevations also altered the continental connections, for North and South America were reunited in Miocene times, and western Europe, Greenland, and America were severed late in the Tertiary era, the exact time being as yet not clearly established. With these great changes also must have come about marked alterations in the oceanic currents and, as a consequence, in the distribution of heat and moisture over vast areas of the northern Atlantic lands. It is admitted by all paleontologists that the marine waters of late Pliocene times in the arctic region were cool, and the widespread glacial tills of the Northern Hemisphere are evidence of a glacial climate of varying intensity throughout Pleistocene time.

CONCLUSIONS.

Our studies of the paleometeorology of the earth are summed up in figure 4. We have seen that two marked glacial periods are clearly established. The one best known was of Pleistocene time and the other, less well known in detail, of earliest Permic time. Both were world-wide in their effects, reducing the mean temperatures sufficiently to allow vast accumulations of snow and ice, not only at high altitudes, but even more markedly at low levels, with the glaciers in many places attaining the sea. We also learn that the continental glaciers of Pleistocene time were dominant in polar regions while those of Permic time had their greatest spread from 20° to 40° south of the present equator, and to a far less extent between 20° and 40° in the other hemisphere. There is also some evidence of glaciers in equatorial Africa in Permic time. We may further state that, although Pleistocene glaciation was general in the arctic region, there certainly was none at this pole in early Permic time, because of the widespread and abundant marine faunas that are not markedly unlike those of the Upper Carbonic; as for the South Pole, our knowledge of pre-Pleistocene glaciation is as yet a blank.

A glacial period does not appear to remain constantly cold, but fluctuates between cold glacial climates and warmer interglacial times of varying duration. During the Pleistocene there were, according to the best glaciologists, at least three, if not four, such warmer intervals. The Permic glacial period also had its warmer times, while the interbedded red strata of the Proterozoic tillites seem to point to the same variability. It is this decided temperature fluctuation during the glacial periods that is so very difficult to explain.

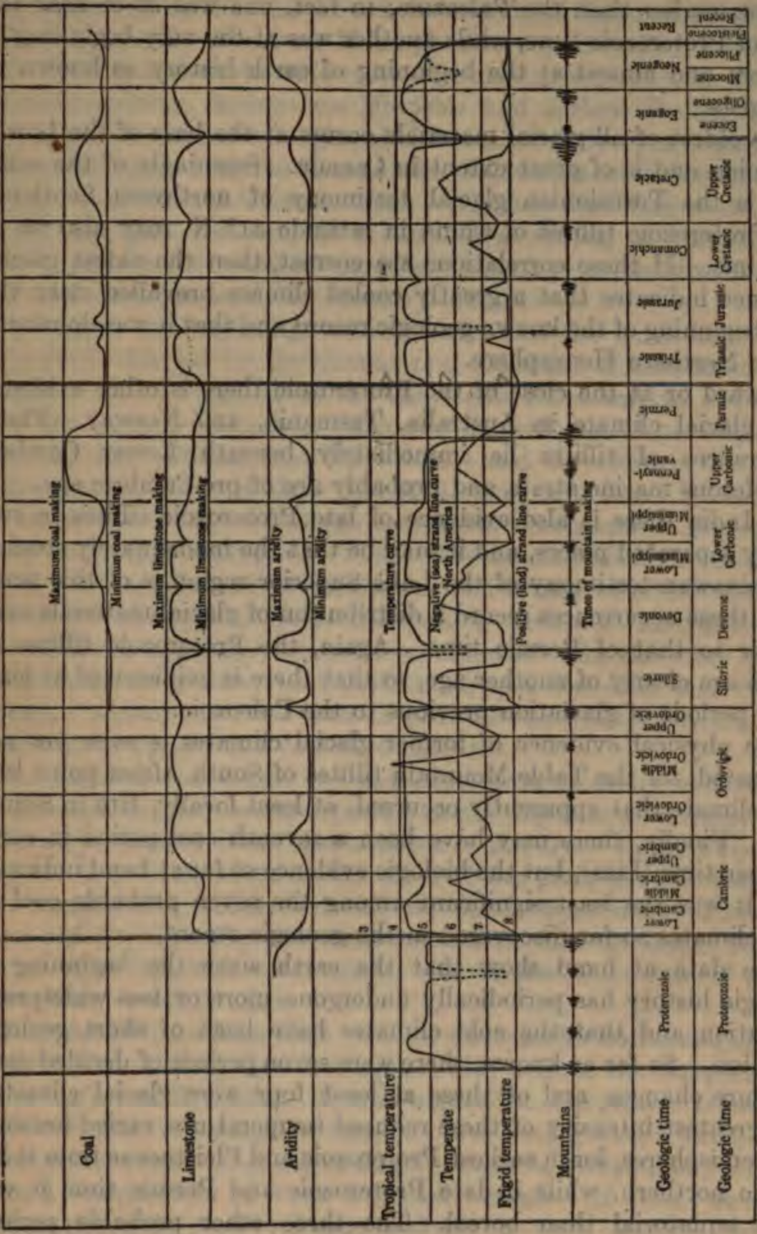

FIG. 4.—Chart of geological climates—Paleometeorology.

In addition to the well-known Pleistocene and Permic glaciation, there is rapidly accumulating a great deal of evidence to the effect that there were at least two and probably three other periods of widespread glacial climates. All of these were geologically very ancient, earlier than the Paleozoic; in fact, one was at or near the close of Proterozoic time, while another was at the very beginning of that era and almost at the beginning of earth history as known to geologists.

The oldest of all glacial materials occurs at the base of the Lower Huronian and is of great extent in Canada. Seemingly of the same time is the Torridonian glacial testimony of northwest Scotland. The Proterozoic tillites of China in latitude 31° N. may also be of this time. If these correlations are correct, then the oldest glacial evidence indicates that a greatly cooled climate prevailed near the very beginning of the known geologic record and that it was dominant in the Northern Hemisphere.

Toward or at the close of the Proterozoic there is other evidence of a glacial climate in Australia, Tasmania, and Norway. These occurrences of tillites lie immediately beneath Lower Cambric fossiliferous marine strata and probably are of pre-Cambric age.

In India there is also evidence of late Proterozoic tillites in two widely separated places, and it may be that the inadequately studied Keweenawan testimony of the Lake Superior region is of this time. If so, these occurrences record a distribution of glacial materials very similar to that of Permic time. Again, the Proterozoic tillites of Africa are clearly of another age, so that there is evidence of at least three periods of glaciation previous to the Paleozoic.

The physical evidence of former glacial climates is even yet not exhausted, for the Table Mountain tillites of South Africa point to a cold climate that apparently occurred, at least locally, late in Siluric time. Finally, there may have been a seventh cool period in early Jurassic time (Lias), but the biologic evidence so far at hand indicates that it was the least significant among the seven probable cool to cold climates so far discovered in the geologic record.

The data at hand show that the earth since the beginning of geologic history has periodically undergone more or less widespread glaciation and that the cold climates have been of short geologic duration. So far as known, there were seven periods of decided temperature changes, and of these at least four were glacial climates. The greatest intensity of these reduced temperatures varied between the hemispheres, for in earliest Proterozoic and Pleistocene time it lay in the northern, while in late Proterozoic and Permic time it was more equatorial than boreal. The three other probable periods of cooled climates are as yet too little known to make out their centers of greatest intensity.

Of the four more or less well-determined glacial periods, at least three (the earliest Proterozoic, Permic, and Pleistocene) occurred *during or directly* after times of intensive mountain making, while the fourth (late Proterozoic) apparently also followed a period of elevation. The Table Mountain tillites of South Africa, if correctly correlated, fall in with the time of the making of the great Caledonian Mountains in the Northern Hemisphere. On the other hand, the very marked and world-wide mountain-making period, with decided volcanic activity, during late Mesozoic and earliest Eocene times, was not accompanied by a glacial climate, but only by a cooled one. The cooled period of the Liassic also followed a mountain-making period, that of late Triassic time. We may therefore state that cooled and cold climates, as a rule, occur during or immediately follow periods of marked mountain making—a conclusion also arrived at independently by Ramsay (1910).

Geologists are beginning to see clearly that the lands have been periodically flooded by the oceans, and the times of maximum submergence and emergence of the continents since earliest Paleozoic time are fairly well known. The two marked glacial periods since Cambric time (Permic and Pleistocene) and the three other more or less cooled climates (late Siluric, Liassic, and late Cretacic) all fall in with the times when the continents were more or less extensively and highly emergent. There were no cold climates when the continents were flooded by the oceans, and it may be added that the periods of widespread limestone-making preceded and followed, but did not accompany, the reduced climates. On the other hand, the periods of greatest coal making (Upper Carbonic and Upper Cretacic) accompanied the time of greatest continental flooding and preceded the appearance of cooled climates.

The more or less coarse red sediments seen at many horizons of the geologic column are interpreted as the deposits of variably arid climates, or those that are alternately wet and dry. In the Paleozoic they are seen more often at the close of the periods when the seas were temporarily withdrawn and the lands were most extensive. These red deposits alternate with formations that are either wholly marine or of brackish-water origin, and in the latter case of gray, green, blue, or black color.

Humphreys has shown that volcanic dust in the isothermal region of the earth's atmosphere does appreciably reduce the temperature at the surface of the globe. It is thought that if explosive volcanoes continued active through a more or less long geologic time, this factor alone would bring on, or largely assist in bringing on, a more reduced temperature or even a glacial climate. If then, we may further postulate that volcanic activity is most marked during times of mountain making, i. e., during the "critical periods" at the close of the eras and the less violent movements at the close of the periods, we should expect ice ages, or at least considerably cooled climates, occurring here also. Let us see how the facts agree with this hypothesis.

Of the "critical periods" at the close of the Paleozoic, Mesozoic, and Cenozoic eras, we know that the first and last were accompanied by glacial climates, but the Mesozoic, though a time of very extensive mountain making and great and prolonged volcanic activity in North America, did not close with a glacial, but only with a slightly cooled climate. Not only this, but we find that volcanism was renewed in the Cordilleras of North America throughout much of the Eocene, and yet there was developed no glacial climate at this time. In the same way the marked temperature reduction at the close of the Cenozoic in the Pleistocene was subsequent to the Miocene and Pliocene movements of this period and not coincident with them, while that of the Paleozoic appears to fall in with the rise of the Urals and Appalachians, though but little volcanism seems to have accompanied the movements in North America. It should also be said that equally extensive movements were going on in Europe in the rise of the European Alps during the geologic times before and after the Permic glaciation, and that the earlier movements did not appreciably affect the climate.

Again, there was decided mountain making toward the close of the Siluric in the formation of the Caledonia Mountains all along western Europe from Spitzbergen to Scotland, with marked volcanic extrusions during the Siluric and early Devonic in Maine, the Maritime Provinces of Canada, and Europe. Yet we have no glacial climate at these times, certainly not in the Northern Hemisphere; rather it seems that the temperature was mild the world over. It is possible, however, that the Table Mountain tillites of South Africa may coincide with this time, and if so a colder temperature affected the Southern Hemisphere only locally.

On the other hand, the "life thermometer" indicates a cooled period at the close of the Triassic and the following Liassic, but this reduction of temperature, again, is geologically subsequent to, rather than coincident with the marked volcanic activity of the Triassic in many widely separated places.

Finally, there were earth movements of considerable magnitude at the close of the Lower Cambric, Ordovicic, and Jurassic that were not accompanied by glacial climates. At all of these times there appears, however, to have been a drop in temperature, slight for the two first-mentioned periods and more marked for the third one, for here we find in the austral region, during earliest Cretacic times, winters alternating with summers.

We may therefore conclude that volcanic dust in the isothermal region of the earth does not appear to be a primary factor in bringing on glacial climates. On the other hand, it can not be denied that such periodically formed blankets against the sun's radiation may have *assisted* in cooling the climates during some of the periods when the *continents were highly* emergent.

It has long been known that during times of intensive mountain-making and more or less cooled climates there was great destruction and alteration of life. The first effects of the environmental changes occurred among the organisms of the land, while the climax of alteration among the marine life appeared later. This is especially well seen in the Permic glaciation, which first blotted out the cosmopolitan Upper Carbonic flora and the insects, while the life of the sea continued without marked change into Middle Permic time. In the later Permic, in the northern equatorial waters of Tethys, occurred the final destruction of many stocks that had long dominated the Paleozoic seas. The explanation of these facts appears to be that on the lands the change of climate takes immediate effect on the organisms, while in the oceans a longer time is consumed in cooling down the warm and equable temperature and in filling all the basins with cold water. Accordingly the last regions in the oceans to come under the influence of glacial climates must be the shallow waters of the equatorial area. The proof of this conclusion is seen in that the last stand made by the marine Paleozoic world is recorded in the deposits of Tethys, the great Mediterranean sea of Permic time. It is also here that we find nearly all of the Paleozoic shallow-water holdovers in the succeeding period, the Triassic.

The cooled but not frigid climate that followed the magnificent mountain making at the close of the Cretacic also produced striking changes in the organic world. These changes were less marked than those of Permic time and more noticeable among the land animals than those of the marine waters, affecting especially the overspecialized, large, thick-shelled, and degenerate stocks.

Great changes were again produced among the large land animals of the world, as well as among those of the polar and temperate oceanic waters, by the glaciation of Pleistocene time. The present shallow waters of the equatorial region still maintain the late Tertiary faunas, and Africa is the asylum where the higher Pliocene land animals have been preserved into our time.

What the effects of the Proterozoic glacial climates were upon the living world of that time it is impossible to say, because we have as yet discovered but little of the organic record.

The marine "life thermometer" indicates vast stretches of time of mild to warm and equable temperatures, with but slight zonal differences between the equator and the poles. The great bulk of marine fossils are those of the shallow seas, and the evolutionary changes recorded in these "medals of creation" are slight throughout vast lengths of time that are punctuated by short but decisive periods of cooled waters and great mortality, followed by quick evolution, and the rise of new stocks. The times of less warmth are the *miotherm* and those of greater heat the *pliotherm* periods of Ramsay (1910).

On the land the story of the climatic changes is different, but in general the equability of the temperature simulates that of the oceanic areas. In other words, the lands also had long-enduring times of mild to warm climates. Into the problem of land climates, however, enter other factors that are absent in the oceanic regions, and these have great influence upon the climates of the continents. Most important of these is the periodic warm-water inundation of the lands by the oceans, causing insular climates that are milder and moister. With the vanishing of the floods somewhat cooler and certainly drier climates are produced. The effect of these periodic floods must not be underestimated, for the North American Continent was variably submerged at least 17 times, and over an area of from 154,000 to 4,000,00 square miles. (Schuchert, 1910.)

When to these factors is added the effect upon the climate caused by the periodic rising of mountain chains, it is at once apparent that the lands must have had constantly varying climates. In general the temperature fluctuations seem to have been slight, but geographically the climates varied between mild to warm pluvial and mild to cool arid. The arid factor has been of the greatest import to the organic world of the lands. Further, when to all of these causes is added the fact that during emergent periods the formerly isolated lands were connected by land bridges, permitting intermigration of the land floras and faunas, with the introduction of their parasites and parasitic diseases,[1] we learn that while the climatic environment is of fundamental importance it is not the only cause for the more rapid evolution of terrestrial life. Unfortunately, the record of land life, and especially of the animal world, is the most imperfect of all paleontologic records until we come to Tertiary time. The known mammal history is a vast one and, although very difficult to interpret from the climatic standpoint, we have in the work of Depéret (1909), Osborn (1910), and Scott (1913) glimpses into the many temperature fluctuations, faunal isolations, and intercontinental radiations of Tertiary time. The history of the Tertiary is the last one of at least three previous and similar records (Mesozoic, later and earlier Paleozoic) of vastly longer eras, taking us back to a time when the lands were without visible life.

In conclusion, it is seemingly clear that the variability in the storage of solar radiation by the earth's atmospheric blanket and by oceanic waters, and the consequent climatic variations of the past and present are due in the main to topographic changes in the earth's crust. These telluric changes alter the configuration of the continents and oceans, the air currents (moist or dry), the oceanic currents (warm, mild, or cool), and the volcanic ash content of the atmosphere.

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[1] This subject is fully discussed by R. T. Eccles, M. D., in the following papers: "Parasitism and natural *selection*," "Importance of disease in plant and animal evolution," "The scope of disease," and "Disease and *genetics*." *Medical Record* for July 31, 1909; Mar. 16, 1912; Mar. 8 and Aug. 2, 1913.

On the other hand, a great deal has been written about the supply and consumption of the carbonic acid of the air as the primary cause for the storage of warmth by the atmospheric blanket. A greater supply of carbon dioxide is said to cause increase of temperature, and a marked subtraction of it will bring on a glacial climate. This aspect of the climatic problem is altogether too large and important to be entered upon here. It is permissible to state, however, that the glacial climates are irregular in their geologic appearance, are variable latitudinally, as is seen in the geographic distribution of the tillites between the poles and the equatorial region, and finally that they appear in geologic time as if suddenly introduced. These differences do not seem to the writer to be conditioned in the main by a greater or smaller amount of carbon dioxide in the atmosphere, for if this gas is so strong a controlling factor, it would seem that at least the glacial climates should not be of such quick development. On the other hand, an enormous amount of carbon dioxide was consumed in the vast limestones and coals of the Cretacic, with no glacial climate as a result; though it must be admitted that the great limestone and vaster coal accumulations of the Pennsylvanic were quickly followed by the Permic glaciation. Again it may be stated that the Pleistocene cold period was preceded in the Miocene and Pliocene by far smaller areas of known accumulations of limestone and coal than during either the Pennsylvanic or Cretacic, and yet a severe glacial climate followed.

Briefly, then, we may conclude that the markedly varying climates of the past seem to be due primarily to periodic changes in the topographic form of the earth's surface, plus variations in the amount of heat stored by the oceans. The causation for the warmer interglacial climates is the most difficult of all to explain, and it is here that factors other than those mentioned may enter.

Granting all this, there still seems to lie back of all these theories a greater question connected with the major changes in paleometeorology. This is: What is it that forces the earth's topography to change with varying intensity at irregularly rhythmic intervals? This difficult and elusive problem the older geologists solved with a great deal of assurance by saying that such change was due to a cooling earth, resulting in periodic shrinkage; but the amount of shrinkage that would necessarily have taken place to account for all the wrinklings and overthrustings of the earth's crust during geologic time would be far greater than that which has apparently occurred. Further, a cooling earth is yet to be demonstrated. Again, some paleogeographers seem to see a periodic heaping up of the oceanic waters in the equatorial region and a pulsatory flowing away later toward the poles. If these observations are not misleading, are we not forced to conclude that the earth's shape changes periodically in response to gravitative forces that alter the body form?

PLEOCHROIC HALOES.[1]

By J. Joly, F. R. S.

[With 3 plates.]

It is now well established that a helium atom is expelled from certain of the radioactive elements at the moment of transformation. The helium atom or alpha ray leaves the transforming atom with a velocity which varies in the different radioactive elements, but which is always very great, attaining as much as 2×10^9 centimeters per second, a velocity which, if unchecked, would carry the atom round the earth in less than two seconds. The alpha ray carries a positive charge of double the ionic amount.

When an alpha ray is discharged from the transforming element into a gaseous medium its velocity is rapidly checked and its energy absorbed. A certain amount of energy is thus transferred from the transforming atom to the gas. We recognize this energy in the gas by the altered properties of the latter; chiefly by the fact that it becomes a conductor of electricity. The mechanism by which this change is effected is in part known. The atoms of the gas, which appear to be freely penetrated by the alpha ray, are so far dismembered as to yield charged electrons or ions, the atoms remaining charged with an equal and opposite charge. Such a medium of free electric charges becomes a conductor of electricity by convection when an electromotive force is applied. The gas also acquires other properties in virtue of its ionization. Under certain conditions it may acquire chemical activity and new combinations may be formed or existing ones broken up. When its initial velocity is expended the helium atom gives up its properties as an alpha ray and thenceforth remains possessed of the ordinary varying velocity of thermal agitation. Bragg and Kleeman and others have investigated the career of the alpha ray when its path or range lies in a gas at ordinary or obtainable conditions of pressure and temperature. We will review some of the facts ascertained.

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[1] Being the Huxley lecture, delivered at the University of Birmingham on Oct. 30, 1912. Reprinted by permission. Published in Bedrock, London, January, 1913.

The range or distance traversed in a gas at ordinary pressures is a few centimeters. The following table, compiled by Geiger, gives the range in air at the temperature of 15° C.:

	Centimeters.		Centimeters.
Uranium 1	2.50	Thorium X	4.30
Uranium 2	2.90	Th emanation	5.00
Ionium	3.00	Thorium A	5.70
Radium	3.30	Thorium C_1	4.80
Ra emanation	4.16	Thorium C_2	8.60
Radium A	4.75	Radioactinium	4.60
Radium C	6.94	Actinium X	4.40
Radium F	3.77	Act emanation	5.70
Thorium	2.72	Actinium A	6.50
Radiothorium	3.87	Actinium C	5.40

It will be seen that the ray of greatest range is that proceeding from thorium C_2, which reaches a distance of 8.6 centimeters. In the uranium family the fastest ray is that of radium C. It attains 6.94 centimeters. There is thus an appreciable difference between the ultimate distances traversed by the most energetic rays of the two families. The shortest ranges are those of uranium 1 and 2.

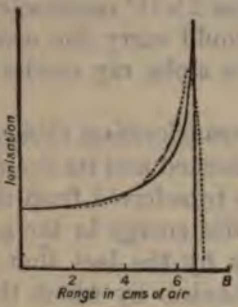

FIG. 1.

The ionization effected by these rays is by no means uniform along the path of the ray. By examining the conductivity of the gas at different points along the path of the ray the ionization at these points may be determined. At the limits of the range the ionization ceases. In this manner the range is, in fact, determined. The dotted curve (fig. 1) depicts the recent investigation of the ionization effected by a sheaf of parallel rays of radium C in air, as determined by Geiger. The range is laid out horizontally in centimeters. The numbers of ions are laid out vertically. The remarkable nature of the results will be at once apparent. We should have expected that the ray at the beginning of its path, when its velocity and kinetic energy were greatest, would have been more effective than toward the end of its range when its energy had almost run out. But the curve shows that it is just the other way. The lagging ray, about to resign its ionizing properties, becomes a much more efficient ionizer than it was at first. The maximum efficiency is, however, in the case of a bundle of parallel rays, not quite at the end of the range, but about half a centimeter from it. The increase to the maximum is rapid, the fall from the maximum to nothing is much more rapid.

It can be shown that the ionization effected anywhere along the path of the ray is inversely proportional to the velocity of the ray at *that* point. But this evidently does not apply to the last 5 or 10 millimeters of the range where the rate of ionization and of the speed of the ray change most rapidly. To what are the changing properties of the rays near the end of their path to be ascribed? It is only recently that this matter has been elucidated.

When the alpha ray has sufficiently slowed down, its power of passing right through atoms, without appreciably experiencing any effects from them, diminishes. The opposing atoms begin to exert an influence on the path of the ray, deflecting it a little. The heavier atoms will deflect it most. This effect has been very successfully investigated by Geiger. It is known as "scattering." The angle of scattering increases rapidly with the decrease of velocity. Now the effect of the scattering will be to cause some of the rays to complete their ranges or, more accurately, to leave their direct line of advance a little sooner than others. In the beautiful experiments of C. T. R. Wilson we are enabled to obtain ocular demonstration of the scattering. The photograph (fig. 2), which I owe to the kindness of Mr. Wilson, shows the deflection of the ray toward the end of its path. In this case the path of the ray has been rendered visible by the condensation of water particles under the influence of the ionization; the atmosphere in which the ray travels being in a state of supersaturation with water vapor at the instant of the passage of the ray. It is evident that if we were observing the ionization along a sheaf of parallel rays, all starting with equal velocity, the effect of the bending of some of the rays near the end of their range must be to cause a decrease in the aggregate ionization near the very end of the ultimate range. For, in fact, some of the rays complete their work of ionizing at points in the gas before the end is reached. This is the cause, or at least an important contributory cause, of the decline in the ionization near the end of the range, when the effects of a bundle of rays are being observed. The explanation does not suggest that the ionizing power of any one ray is actually diminished before it finally ceases to be an alpha ray.

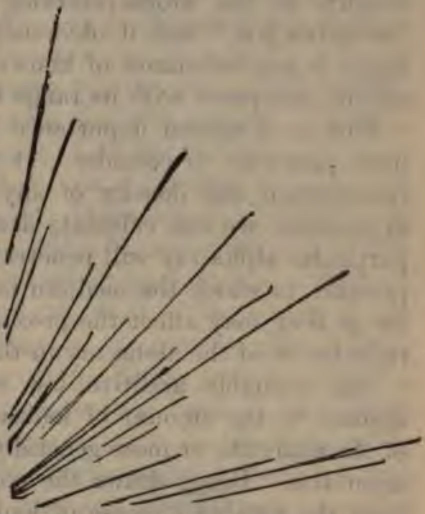

FIG. 2.

The full line in figure 1 gives the ionization curve which it may be expected would be struck out by a single alpha ray. In it the ionization goes on increasing till it abruptly ceases altogether, with the entire loss of the initial kinetic energy of the particle.

A highly remarkable fact was found out by Bragg. The effect of the atom traversed by the ray to check the velocity of the ray is independent of the physical and chemical condition of the atom. He measured the "stopping power" of a medium by the distance the ray can penetrate into it compared with the distance to which it can penetrate in air. The less the ratio the greater the stopping power. The stopping power of a substance is proportional to the square root of its atomic weight. The stopping power of an atom is not altered if it is in chemical union with another atom. The atomic weight is the one quality of importance. The physical state, whether the element is in the solid, liquid, or gaseous state, is unimportant. And when we deal with molecules the stopping power is simply proportional to the sum of the square roots of the atomic weights of the atoms entering into the molecule. This is the "additive law," and it obviously enables us to calculate what the range in any substance of known chemical composition and density will be, compared with its range in air.

This is of special importance in connection with phenomena we have presently to consider. It means that, knowing the chemical composition and density of any medium whatsoever, solid, liquid, or gaseous, we can calculate accurately the distance to which any particular alpha ray will penetrate. Nor have the temperature and pressure to which the medium is subjected any influence save in so far as they may affect the proximity of one atom to another. The retardation of the alpha ray in the atom is not affected.

This valuable additive law can not, however, in strictness be applied to the amount of ionization attending the ray. The form of the molecule, or more generally its volume, may have an influence upon this. Bragg draws the conclusion, from this fact as well as from the notable increase of ionization with loss of speed, that the ionization is dependent upon the time the ray spends in the molecule. The energy of the ray is, indeed, found to be less efficient in producing ionization in the smaller atoms.

Before leaving our review of the general laws governing the passage of alpha rays through matter, a point of interest must be referred to. We have hitherto spoken in general terms of the fact that ionization attends the passage of the ray. We have said nothing as to the nature of the ionization so produced. But in point of fact the ionization due to an alpha ray is sui generis. A glance at one of Wilson's photographs (fig. 2) illustrates this. The white streak of water particles marks the path of the ray. The ions produced are evidently closely crowded along the track of the ray. They have been called into existence in a very minute instant of time. Now we know that ions of opposite sign if left to themselves recombine. The rate of recombination depends upon the product of the number of each sign present in unit volume. Here the numbers are very great and the volume very small. The ionic density is therefore high, and recombination very rapidly removes the ions after they are formed. We see here a peculiarity of the ionization effected by alpha rays. It is linear in distribution and very local. Much of the ionization in gases is again undone by recombination before diffusion leads to the separation of the ions. This "initial recombination" is greatest toward the end of the path of the ray where the ionization is a maximum. Here it may be so effective that the form of the curve is completely lost unless a very large electromotive force is used to separate the ions when the ionization is being investigated.

We have now reviewed recent work at sufficient length to understand something of the nature of the most important advance ever made in our knowledge of the atom. Let us glance briefly at what we have learned. The radioactive atom in sinking to a lower atomic weight casts out with enormous velocity an atom of helium. It thus loses a definite portion of its mass and of its energy. Helium, which is chemically one of the most inert of the elements, is, when possessed of such great kinetic energy, able to penetrate and ionize the atoms which it meets in its path. It spends its energy in the act of ionizing them, coming to rest, when it moves in air, in a few centimeters. Its particular initial velocity depends upon which of the radioactive elements has given rise to it. The length of its path is therefore different according to the radioactive element from which it proceeds. The retardation which it experiences in its path depends entirely upon the atomic weight of the atoms which it traverses. As it advances in its path its effectiveness in ionizing the atom rapidly increases and attains a very marked maximum. In a gas the ions produced being much crowded together recombine rapidly; so rapidly that the actual ionization may be quite concealed unless a sufficiently strong electric force is applied to separate them. Such is a brief summary of the climax of radioactive discovery—the birth, life, and death of the alpha ray. Its advent into science has altered fundamentally our conception of matter. It is fraught with momentous bearings upon geological science. How the work of the alpha ray is sometimes recorded visibly in the rocks and what we may learn from that record I propose now to bring before you.

In certain minerals, notably the brown variety of mica known as biotite, the microscope reveals minute circular marks occurring here and there, quite irregularly. The most usual appearance is that of a circular area darker in color than the surrounding mineral. The radii of these little disk-shaped marks when well defined are found to be remarkably uniform, in some cases four-hundredths of a millimeter and in others three-hundredths, about. These are the measurements in biotite. In other minerals the measurements are not quite the same as in biotite. Such minute objects are quite invisible to the naked eye. In some rocks they are very abundant, indeed they may be crowded together in such numbers as to darken the color of the mineral containing them. They have long been a mystery to petrologists.

Close examination shows that there is always a small speck of a foreign body at the center of the circle, and it is often possible to identify the nature of this central substance, small though it be. Most generally it is found to be the mineral zircon. Now, this mineral was shown by Strutt to contain radium in quantities much exceeding those found in ordinary rock substances. Some other mineral may occasionally form the nucleus, but we never find any which is not known to be specially likely to contain a radioactive substance. Another circumstance we notice. The smaller this central nucleus the more perfect in form is the darkened circular area surrounding it. When the circle is very perfect and the central mineral clearly defined at its center we find by measurement that the radius of the darkened area is generally 0.033 millimeter. It may sometimes be 0.040 millimeter. These are always the measurements in biotite. In other minerals the radii are a little different.

We see in the photograph (pl. 1, fig. 1), much magnified, a halo contained in biotite. We are looking at a region in a rock section, the rock being ground down to such a thickness that light freely passes through it. The biotite is in the center of the field. Quartz and feldspar surround it. The rock is a granite. The biotite is not all one crystal. Two crystals, mutually inclined, are cut across. The halo extends across both crystals, but owing to the fact that polarized light is used in taking the photograph it appears darker in one crystal than in the other. We see the zircon which composes the nucleus. The fine lineated appearance of the biotite is due to the cleavage of that mineral, which is cut across in the section.

The question arises whether the darkened area surrounding the zircon may not be due to the influence of the radioactive substances contained in the zircon. The extraordinary uniformity of the radial measurements of perfectly formed haloes (to use the name by which they have long been known) suggests that they may be the result of alpha radiation. For in that case, as we have seen, we can at once account for the definite radius as simply representing the range of the ray in biotite. The farthest-reaching ray will define the radius of the halo. In the case of the uranium family this will be radium C, and in the case of thorium it will be thorium C. Now

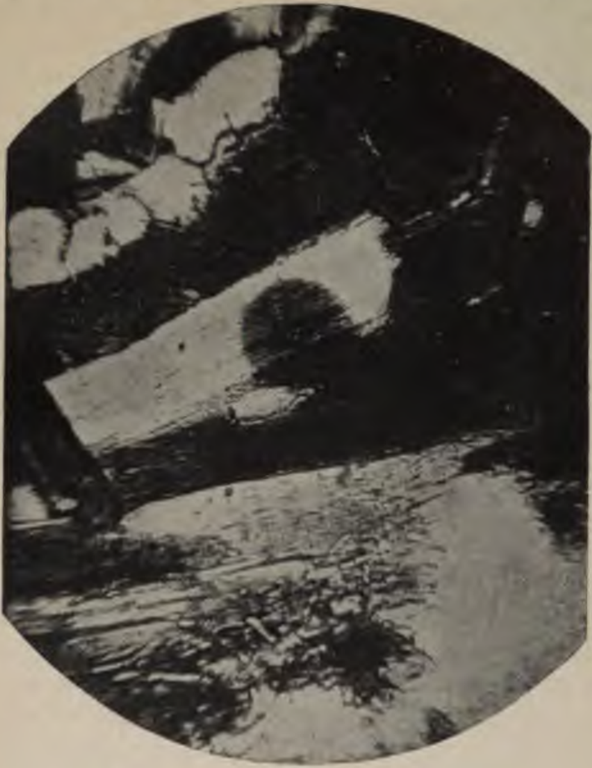

FIG. 1.

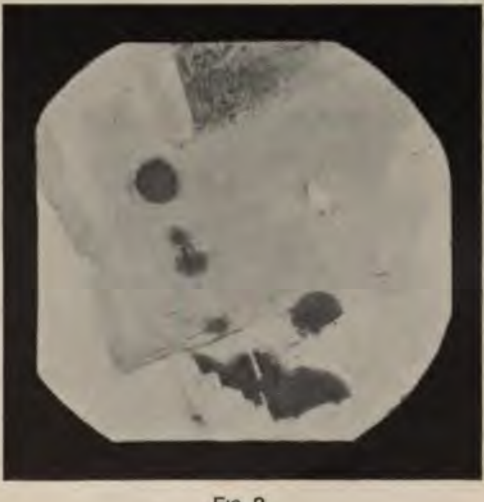

FIG. 2.

PLEOCHROIC HALOES.

here we possess a means of at once confirming or rejecting the view that the halo is a radioactive phenomenon and occasioned by alpha radiation; for we can calculate what the range of these rays will be in biotite, availing ourselves of Bragg's additive law, already referred to. When we make this calculation we find that radium C just penetrates 0.033 millimeter and thorium C 0.040 millimeter. The proof is complete that we are dealing with the effects of alpha rays. Observe now that not only is the coincidence of measurement and calculation a proof of the view that alpha radiation has occasioned the halo, but it is a very complete verification of the important fact stated by Bragg, that the stopping power depends solely on the atomic weight of the atoms traversed by the ray.

We have seen that our examination of the rocks reveals only the two sorts of halo, the radium halo and the thorium halo. This is not without teaching. For why not find an actinium halo? Now, Rutherford long ago suggested that this element and its derivatives were probably an offspring of the uranium family; a side branch, as it were, in the formation of which relatively few transforming atoms took part. On Rutherford's theory, then, actinium should always accompany uranium and radium, but in very subordinate amount. The absence of actinium haloes clearly supports this view. For if actinium was an independent element we would be sure to find actinium haloes. The difference in radius should be noticeable. If, on the other hand, actinium was always associated with uranium and radium, then its effects would be submerged in those of the much more potent effects of the uranium series of elements.

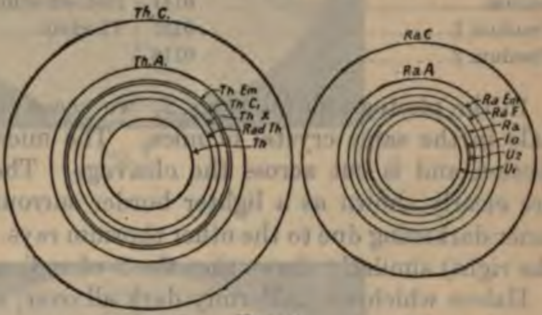

FIG. 3.

It will have occurred to you already that if the radioactive origin of the halo is assured the shape of a halo is not really circular, but spherical. This is so. There is no such thing as a disk-shaped halo. The halo is a spherical volume containing the radioactive nucleus at its center. The true radius of the halo may, therefore, only be measured on sections passing through the nucleus.

In order to understand the mode of formation of a halo we may profitably study on a diagram the events which go on within the halo sphere. Such a diagram is seen in figure 3. It shows to relatively correct scale the limiting range of all the alpha-ray producing members of the uranium and thorium families. We know that each member of a family will exist in equilibrium amount within the nucleus possessing the parent element. Each alpha ray leaving the nucleus will just attain its range and then cease to affect the mica. Within the halo sphere there must be, therefore, the accumulated effects of the influences of all the rays. Each has its own sphere of influence, and the spheres are all concentric.

The radii in biotite of the several spheres are given in the following table:

URANIUM FAMILY.	Millimeter.	THORIUM FAMILY.	Millimeter.
Radium C	0.0330	Thorium C_2	0.040
Radium A	.0224	Thorium A	.026
Ra emanation	.0196	Th emanation	.023
Radium F	.0177	Thorium C_1	.022
Radium	.0156	Thorium X	.020
Ionium	.0141	Radiothorium	.019
Uranium 1	.0137	Thorium	.013
Uranium 2	.0118		

In the photograph (pl 1, fig. 2) we see a uranium and a thorium halo in the same crystal of mica. The mica is contained in a rock section and is cut across the cleavage. The effects of thorium C_2 are clearly shown as a lighter border surrounding the accumulated inner darkening due to the other thorium rays. The uranium halo (to the right) similarly shows the effects of radium C, but less distinctly.

Haloes which are uniformly dark all over, as described above, are, in point of fact, "overexposed," to borrow a familiar photographic term. Haloes are found which show much very beautiful internal detail. Too vigorous action obscures this detail just as detail is lost in an overexposed photograph. We may again have "underexposed" haloes in which the action of the several rays is incomplete or in which the action of certain of the rays has left little if any trace. Beginning at the most underexposed haloes we find circular dark marks having the radius 0.012 or 0.013 millimeter. These haloes are due to uranium, although their inner darkening is doubtless aided by the passage of rays which were too few to extend the darkening beyond the vigorous effects of the two uranium rays. Then we find haloes carried out to the radii 0.016, 0.018, and 0.019 millimeter. The last sometimes show very beautiful outer rings having radial dimensions such as would be produced by radium A and radium C. Finally we may have haloes in which interior detail is lost so far out as the radius due to emanation or radium A, while outside this floats the ring due to radium C. Certain variations of these effects may occur, marking, apparently, different stages of exposure. Plate 2 illustrates some of these stages, figure 2 of this plate being greatly enlarged to show clearly the halo sphere of radium A.

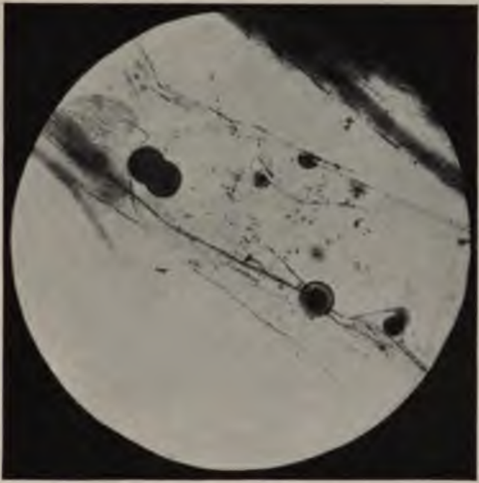

FIG. 1.

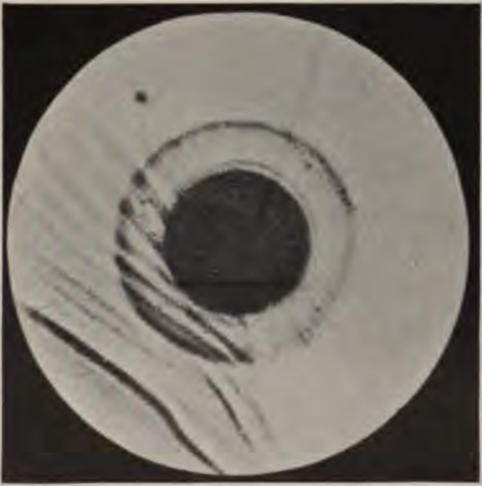

FIG. 2.

PLEOCHROIC HALOES.

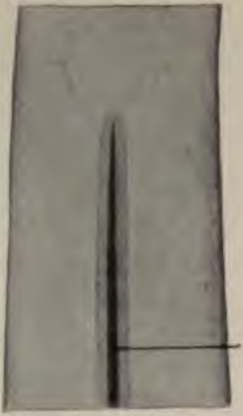

FIG. 1.

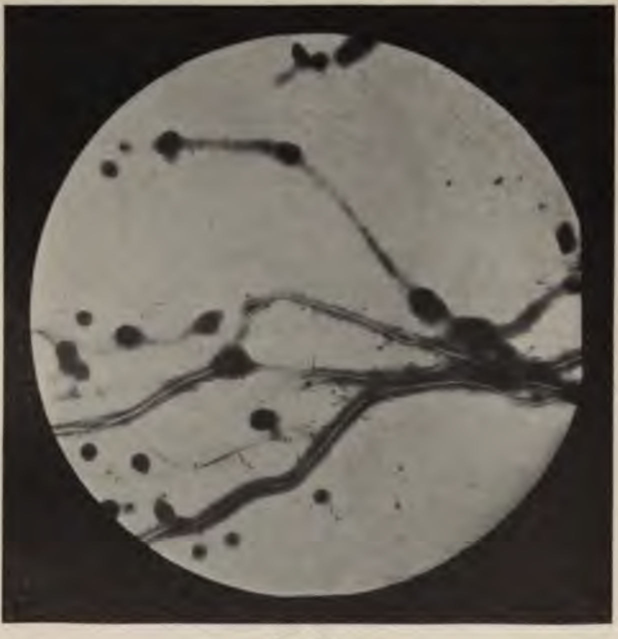

FIG. 2.

PLEOCHROIC HALOES.

In most of the cases referred to above the structure evidently shows the existence of concentric spherical shells of darkened biotite. This is a very interesting fact, for it proves that in the mineral the alpha ray gives rise to the same increased ionization toward the end of its range as Bragg determined in the case of gases; and we must conclude that the halo in every case grows in this manner. A spherical shell of darkened biotite is first produced, and the inner coloration is only effected as the more feeble ionization along the track of the ray in course of ages gives rise to sufficient alteration of the mineral. This more feeble ionization is, near the nucleus, enhanced in its effects by the fact that there all the rays combine to increase the ionization, and, moreover, the several tracks are there crowded by the convergency to the center. Hence the most elementary haloes seldom show definite rings due to uranium, etc., but appear as embryonic disk-like markings. The photographs on the screen[1] illustrate many of the phases of halo development. Rutherford succeeded in making a halo artificially by compressing into a capillary glass tube a quantity of the emanation of radium. As the emanation decayed the various derived products came into existence and all the several alpha rays penetrated the glass, darkening the walls of the capillary out to the limit of the range of radium C in glass. Figure 1 on plate 3 is a magnified view of the tube. The dark central part is the capillary. The tubular halo surrounds it. This experiment has, however, been anticipated by some scores of millions of years, for here is the same effect in a biotite crystal (pl. 3, fig. 2). Along what are apparently tubular passages or cracks in the mica a solution rich in radioactive substances has moved, probably during the final consolidation of the granite in which the mica occurs. A continuous and very regular halo has developed along these conduits. A string of halo spheres may lie along such passages. We must infer that solutions or gases able to establish the radioactive nuclei moved along these conduits, and we are entitled to ask if all the haloes in this biotite are not, in this sense, of secondary origin. There is, I may add, much to support such a conclusion.

It must not be thought that the underexposed halo is a recent creation. By no means. All are old, appallingly old; and in the same rock all are probably of the same, or nearly the same, age. The underexposure is simply due to a lesser quantity of the radioactive elements in the nucleus. They are underexposed, in short, not because of lesser duration of exposure, but because of insufficient action, as when in taking a photograph the stop is not open enough for the time of the exposure.

The halo has so far told us that the additive law is obeyed in solid media and that the increased ionization attending the slowing down of the ray obtaining in gases also obtains in solids, for otherwise the halo would not commence its development as a spherical shell or envelope. But here we learn that there is probably a certain difference in the course of events attending the immediate passage of the ray in the gas and in the solid. In the former initial recombination may obscure the intense ionization near the end of the range. We can only detect the true end effects by artificially separating the ions by a strong electric force. If this recombination happened in the mineral we should not have the concentric spheres so well defined as we see them to be. What, then, hinders the initial recombination in the solid? The answer probably is that the newly formed ion is instantly used up in a fresh chemical combination. Nor is it free to change its place, as in the gas. There is simply a new equilibrium brought about by its sudden production. In this manner the conditions in the complex molecule of biotite, tourmaline, etc., may be quite as effective in preventing initial recombination as the most effective electric force we could apply. The final result is that we find the Bragg curve reproduced most accurately in the delicate shading of the rings making up the perfectly exposed halo.

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[1] Shown by lecturer but not here reproduced.

That the shading of the rings reproduces the form of the Bragg curve projected, as it were, upon the line of advance of the ray and reproduced in depth of shading, shows that in yet another particular the alpha ray behaves much the same in the solid as in the gas. A careful examination of the outer edge of the circles always reveals a steep but not abrupt cessation of the action of the ray. Now, Geiger has investigated and proved the existence of scattering of the alpha ray by solids. We may therefore suppose, with much probability, that there is the same scattering within the mineral near the end of the range. The heavy iron atom of the biotite is, doubtless, chiefly responsible for this in biotite haloes. I may observe that this shading of the outer bounding surface of the sphere of action is found however minute the central nucleus. In the case of a nucleus of considerable size another effect comes in which tends to produce an enhanced shading. This will result if rays proceed from different depths in the nucleus. If the nucleus was of the same density and atomic weight as the surrounding mica there would be little effect. But its density and molecular weight are generally greater, hence the retardation is greater, and rays proceeding from deep in the nucleus experience more retardation than those which proceed from points near to the surface. The distances reached by the rays in the mica will vary accordingly, and so there will be a gradual cessation of the effects of the rays.

The result of our study of the halo may be summed up in the statement that in nearly every particular we have the phenomena which have been measured and observed in the gas reproduced on a minute scale in the halo. Initial recombination seems, however, to be absent or diminished in effectiveness; probably because of the new stability instantly assumed by the ionized atoms.

One of the most interesting points about the halo remains to be referred to. The halo is always uniformly darkened all round its circumference and is perfectly spherical. Sections, whether taken in the plane of cleavage of the mica or across it, show the same exactly circular form, and the same radius. Of course, if there was any appreciable increase of range along or across the cleavage the form of the halo on the section across the cleavage should be elliptical. The fact that there is no measurable ellipticity is, I think, one which would not on first consideration be expected.

For what are the conditions attending the passage of the ray in a medium such as mica? According to crystallographic conceptions we have here an orderly arrangement of molecules, the units composing the crystal being alike in mass, geometrically spaced, and polarized as regards the attractions they exert one upon another. Mica, more especially, has the cleavage phenomenon developed to a degree which transcends its development in any other known substance. We can cleave it and again cleave it till its flakes float in the air, and we may yet go on cleaving it by special means till the flakes no longer reflect visible light. And not less remarkable is the uniplanar nature of its cleavage. There is little cleavage in any plane but the one, although it is easy to show that the molecules in the plane of the flake are in orderly arrangement and are more easily parted in some directions than in others. In such a medium beyond all others we must look with surprise upon the perfect sphere struck out by the alpha rays, because it seems certain that the cleavage is due to lesser attraction, and, probably, further spacing of the molecules, in a direction perpendicular to the cleavage.

It may turn out that the spacing of the molecules will influence but little the average number per unit distance encountered by rays moving in divergent paths. If this is so we seem left to conclude that in spite of its unequal and polarized attractions there is equal retardation and equal ionization in the molecule in whatever direction it is approached. Or, again, if the encounters indeed differ in number, then some compensating effect must exist whereby a direction of lesser linear density involves greater stopping power in the molecule encountered, and vice versa.

The nature of the change produced by the alpha rays is unknown. But the formation of the halo is not, at least in its earlier stages, attended by destruction of the crystallographic and optical properties of the medium. The optical properties are unaltered in nature but increased in intensity. This applies till the halo has become so darkened that light is no longer transmitted under the conditions of thickness obtaining in rock sections. It is well known that there is in biotite a maximum absorption of a plane polarized light ray when the plane of vibration coincides with the plane of cleavage. A section across the cleavage then shows a maximum amount of absorption. A halo seen on this section simply produces this effect in a more intense degree. This is well shown in figure 1 (plate 1) on a portion of the halo sphere. The descriptive name "pleochroic halo" has originated from this fact. We must conclude that the effect of the ionization due to the alpha ray has not been to alter fundamentally the conditions which give rise to the optical properties of the medium. The increased absorption is probably associated with some change in the chemical state of the iron present. Haloes are, I believe, not found in minerals from which this element is absent. One thing is quite certain. The coloration is not due to an accumulation of helium atoms, i. e., of spent alpha rays. The evidence for this is conclusive. If helium was responsible we should have haloes produced in all sorts of colorless minerals. Now we sometimes see zircons in feldspars and in quartz, etc., but in no such case is a halo produced. And halo spheres formed within and sufficiently close to the edge of a crystal of mica are abruptly truncated by neighboring areas of feldspar or quartz, although we know that the rays must pass freely across the boundary. Again it is easy to show that even in the oldest haloes the quantity of helium involved is so small that one might say the halo sphere was a tolerably good vacuum as regards helium. There is, finally, no reason to suppose that the imprisoned helium would exhibit such a coloration, or, indeed, any at all.

I have already referred to the great age of the halo. Haloes are not found in the younger igneous rocks. It is probable that a halo less than a million years old has never been seen. This, prima facie, indicates an extremely slow rate of formation. And our calculations quite support the conclusions that the growth of a halo, if this has been uniform, proceeds at a rate of almost unimaginable slowness.

Let us calculate the number of alpha rays which may have gone to form a halo in the Devonian granite of Leinster.

It is common to find haloes developed perfectly in this granite and having a nucleus of zircon less than 5×10^{-4} centimeter in diameter. The volume of zircon is 65×10^{-12} cubic centimeter and the mass 3×10^{-10} gram, and if there was in this zircon 10^{-8} gram radium per gram (a quantity about five times the greatest amount measured by Strutt), the mass of radium involved is 3×10^{-18} gram. From this and from the fact ascertained by Rutherford that the number of alpha rays expelled by a gram of radium in one second is 3.4×10^{10}, we find that three rays are shot from the nucleus in a year. *If now,* geological time since the Devonian is 50 millions of years, then 150 millions of rays built up the halo. If geological time since the Devonian is 400 millions of years, then 1,200 millions of alpha rays are concerned in its genesis. The number of ions involved, of course, greatly exceeds these numbers. A single alpha ray fired from radium C will produce 2.37×10^5 ions in air.

But haloes may be found quite clearly defined and fairly dark out to the range of the emanation ray and derived from much lesser quantities of radioactive materials. Thus a zircon nucleus with a diameter of but 3.4×10^{-4} centimeter formed a halo strongly darkened within, and showing radium A and radium C as clear smoky rings. Such a nucleus, on the assumption made above as to its radium content, expels one ray in a year. But, again, haloes are observed with less blackened pupils and with faint ring due to radium C, formed round nuclei of rather less than 2×10^{-4} centimeter diameter. Such nuclei would expel one ray in five years. And even lesser nuclei will generate in these old rocks haloes with their earlier characteristic features clearly developed. In the case of the most minute nuclei, if my assumption as to the uranium content is correct, an alpha ray is expelled, probably, no oftener than once in a century, and possibly at still longer intervals.

The equilibrium amount of radium contained in some nuclei may amount to only a few atoms. Even in the case of the larger nuclei and more perfectly developed haloes the quantity of radium involved is many millions of times less than the least amount we can recognize by any other means. But the delicacy of the observation is not adequately set forth in this statement. We can not only tell the nature of the radioactive family with which we are dealing, but we can recognize the presence of some of its constituent members. I may say that it is not probable the zircons are richer in radium than I have assumed. My assumption involves about 3 per cent of uranium. I know of no analyses ascribing so great an amount of uranium to zircon. The variety cyrtolite has been found to contain half this amount, about. But even if we doubled our estimate of radium content, the remarkable nature of our conclusions is hardly lessened.

It may appear strange that the ever-interesting question of the earth's age should find elucidation from the study of haloes. Nevertheless the subjects are closely connected. The circumstances are as follows: Geologists have estimated the age of the earth since denudation began, by measurements of the integral effects of denudation. These methods agree in showing an age of about 10^8 years. On the other hand, measurements have been made of the accumulation in minerals of radioactive débris—the helium and lead—and results obtained which, although they do not agree very well among themselves, are concordant in assigning a very much greater age to the rocks. If the radioactive estimate is correct, then we are now living in a time when the denudative forces of the earth are about eight or nine times as active as they have been on the average over the past. Such a state of things is absolutely unaccountable. And all the more unaccountable because from all we know we would expect a somewhat lesser rate of solvent denudation as the world gets older and the land gets more and more loaded with the washed-out materials of the rocks.

Both the methods referred to of finding the age assume the principle of uniformity. The geologist contends for uniformity throughout the past physical history of the earth. The physicist claims the like for the change rates of the radioactive elements. Now the study of the rocks enables us to infer something as to the past history of our globe. Nothing is, on the other hand, known respecting the origin of uranium or thorium—the parent radioactive bodies. And while not questioning the law and regularity which undoubtedly prevail in the periods of the members of the radioactive families, it appears to me that it is allowable to ask if the change rate of uranium has been always what we now believe it to be. This comes to much the same thing as supposing that atoms possessing a faster change rate once were associated with it which were capable of yielding both helium and lead to the rocks. Such atoms might have been collateral in origin with uranium from some antecedent element. Like helium, lead may be a derivative from more than one sequence of radioactive changes. In the present state of our knowledge the possibilities are many. The change rate is known to be connected with the range of the alpha ray expelled by the transforming element; and the conformity of the halo with our existing knowledge of the ranges is reason for assuming that, whatever the origin of the more active associate of uranium, this passed through similar elemental changes in the progress of its disintegration. There may, however, have been differences in the ranges which the halo would not reveal. It is remarkable that uranium at the present time is apparently responsible for two alpha rays of very different ranges. If these proceed from different elements, one should be faster in its change rate than the other. Some guidance may yet be forthcoming from the study of the more obscure problems of radioactivity.

Now, it is not improbable that the halo may contribute directly to this discussion. We can evidently attack the biotite with a known number of alpha rays and determine how many are required to produce a certain intensity of darkening, corresponding to that of a halo with a nucleus of measurable dimensions. On certain assumptions, which are correct within defined limits, we can calculate, as I have done above, the number of rays concerned in forming the halo. In doing so we assume some value for the age of the halo. Let us take the maximum radioactive value. A halo originating in Devonian times may attain a certain central blackening from the effects of, say, 10^8 rays. But now suppose we find that we can not produce the same degree of blackening with this number of rays applied in the laboratory. What are we to conclude? I think there is only the one conclusion open to us, that some other source of alpha rays, or a faster rate of supply, existed in the past. And this conclusion would explain the absence of haloes from the younger rocks; which, in view of the vast range of effects possible in the development of haloes, is, otherwise, not easy to account for. It is apparent that the experiment on the biotite has a direct bearing on the validity of the radioactive method of estimating the age of the rocks. It is now being carried out by Prof. Rutherford under reliable conditions.

Finally, there is one very certain and valuable fact to be learned from the halo. The halo has established the extreme rarity of radioactivity as an atomic phenomenon. One and all of the speculations as to the slow breakdown of the commoner elements may be dismissed. The halo shows that the mica of the rocks is radioactively sensitive. The fundamental criterion of radioactive change is the expulsion of the alpha ray. The molecular system of the mica and of many other minerals is unstable in presence of these rays, just as a photographic plate is unstable in presence of light. Moreover, the mineral integrates the radioactive effects in the same way as a photographic salt integrates the effects of light. In both cases the feeblest activities become ultimately apparent to our inspection. We have seen that one ray in each year since the Devonian period will build the fully formed halo, unlike any other appearance in the rocks. And we have been able to allocate all the haloes so far investigated to one or the other of the known radioactive families. We are evidently justified in the belief that had other elements been radioactive we must either find characteristic haloes produced by them, or else find a complete darkening of the mica. The feeblest alpha rays emitted by the relatively enormous quantities of the prevailing elements, acting over the whole duration of geological time—and it must be remembered that the haloes we have been studying are comparatively young—must have registered their effects on the sensitive minerals. And thus we are safe in concluding that the common elements, and, indeed, many which would be called rare, are possessed of a degree of stability which has preserved them unchanged since the beginning of geological time. Each unaffected flake of mica is, thus, unassailable proof of a fact which but for the halo would, probably, have been forever beyond our cognizance.

THE GEOLOGY OF THE BOTTOM OF THE SEAS.[1]

By L. de Launay,
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Notwithstanding so many important discoveries, the oldest of which date back scarcely more than a century and a half, geology, a very young science, is still full of mystery. We are laboriously trying to reconstruct a story which had no human witnesses, the traces of which have been for the greater part destroyed or are to-day buried under the mountains or the seas at depths compared with which the thickness of the ash which covers Pompeii seems trivial. Little by little we bring together again some scattered shreds; we compare them with present phenomena which seem to us to offer an analogy, and proceeding by inference we try to reach some general conclusions which by later investigation we may verify experimentally in certain details. But at least we must have the testimony as full as possible of all these existing traces of ancient phenomena or of present comparable phenomena. All that the geologist can do is to go over the surface of the globe, hammer in hand, observing and collecting as he goes. As a rule, he does not dig; he personally does not search below the surface, for the means, except in some favored countries, would be lacking for that work. He is therefore compelled to plead, to beg for aid in every quarter. He asks it chiefly from miners, from well diggers, from builders of tunnels and from excavators who penetrate beneath the soil for him. He seeks it from explorers, who, though inexperienced in geology, visit the less accessible regions of the globe, the deserts, the polar glaciers. He will demand it even from astronomers who bring him cosmic elements for comparison and to whom he will try in exchange to furnish, for the interpretation of a vast universe, positive evidences and precise facts established on our little earth. He will demand much—and this is the point which I wish to examine—from oceanographers whose bold explorations have for their aim to in some degree increase our knowledge of what we here term the geology of the bottom of the seas.

Oceanography is the geology of the future just as physical geography is in certain respects the geology of the present and as geology proper is, above all, the reconstruction of the past.

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[1] Stenographic report of a lecture before the Institut Oceanographique de Paris, November 22, 1913. Translated by permission from Revue Scientifique, Paris, Jan. 3, 1914.

At the bottom of the seas, side by side with the continuous work of natural forces—of gravity, of chemical precipitations and dissolutions—myriads of beings live and die, innumerable generations succeed each other and develop to finally accumulate inert deposits, which in later millions of years shall become the sedimentary formations of a new land just as to-day in Touraine, in Normandy, in Champagne the chalky limestones which nourish our crops and from which we extract material for the construction of our houses are the product of bryozoans, of foraminifera of the Cretaceous age. A glance at the geological formations which make up the solid substratum of our arable land is enough by the presence of innumerable remains of marine shells to establish the fact that the greater part of these chalk beds were formed in the seas. Beside these marine sediments the lake, river, and other sediments play but a minor part. And if in comparison with the sedimentary deposits proper we considered the formations due to another great source of terrestrial activity—fire—we could show, disregarding the plutonic rocks, that the evidences of these igneous rocks occupy a limited area at the surface. It is true that the plutonic rocks would soon predominate if we could dig down a short distance into the crust of the globe. At a depth of 2 or 3 kilometers (which appears to us enormous because we are very small and because our tools are very insufficient, but which is only a shallow depth in the 6,400 kilometers of radius of the earth), we should find the sediments would disappear, giving place almost exclusively to igneous rocks. But this geology of the depths, which perhaps will be the geology of our successors, unfortunately is not yet for us. And if one is limited as we are to the surface of the earth, the part played by the waters, especially by the marine waters, becomes absolutely predominant.

Geology was made by the waters; it was made by the seas. If water, as it is passing away in other worlds, had not existed at the surface, this geology would be altogether different; and the day when active water shall have disappeared from the surface of the earth, which may happen, though perhaps only by congealing, the land will be dead; its geological history, as we understand it at least, will be ended.

Thus oceanography permits us to see in operation before us this work of the waters, which has played such a preponderant part in the construction of the earth's crust. There are some sediments, comparable to those of geological strata, which are now in process of formation in the seas, just as the scenery prepared in the mysterious places beneath the stage of a theater is caused at a given moment to spring up to alter the scene. Of the method of these great changes at which we can not be present, but of which the ancient equivalent constitutes our geologic history, oceanography informs us. The explorations undertaken with so much success during the past years in ocean depths show us similar strata in process of deposition and enable us in a measure to be present at the first stage—the submarine stage—of those sediments whose ancient equivalents have had likewise in their turn a history now terrestrial, now marine or lacustrine again, so complicated, so changeable with vicissitudes so diverse and such changing fortunes.

We must not forget, however, and on this point I must insist because it is fundamental, that what to-day is the land, was yesterday, and to-morrow may again be, the ocean. Our moving and changing earth, while carried on its unbridled course through space, is unceasingly developing and is transformed, just as are the living beings on its surface, whose changes we can see, by laws which though of another nature have none the less, in their origin, one and the same cause—the very general principle of tendency to equilibrium and to least resistance. The movements of the waters pass and repass over our continents like the tides on a beach. Twenty times in the short period which represents one of our geologic stages a locality like Paris has been covered by the floods or has emerged again. There is not a spot on our globe which has not, like that Atlantis whose history last year M. Termier so eloquently recalled to us, been submerged by the ocean after having been inhabited for a time by terrestrial beings. And to-morrow, perhaps, if geologic history continues, as everything indicates it will, some new changes of the same order may be produced, for example, in the troubled zone of our Mediterranean Sea—the emergence here of lands and the reflux of the seas driven from their old bed coming to submerge the continents. The features which seem to us the most essential of our present physical geography are only entirely momentary forms, provisional and ephemeral, destined to disappear in this perpetual movement of destruction and construction, in this incessant turmoil of forces and of matter which moves the universe in space as well as the atoms in a grain of sand. Geology teaches us also that the highest elevations of the globe, those which to men of antiquity seemed to constitute the oldest parts of the earth, the bodies of titans struck by lightning in their fight against the heavens, the Alps, the Caucasus, and the Himalayas, are quite recent wrinkles of our crust, the heights and escarpments of which remain only because time has so far failed to erode and destroy them. It shows us likewise in the deepest abysses of the sea some recently formed hollows.

By reason of these incessant movements, while the bottom of the seas is the laboratory where future continents are made, it is also the vast tomb where are concealed and preserved, in such measure as the mummy of the past may be preserved, certain continents that have disappeared. The geology of the marine substrata has no reason for being different from the geology of the continents save the inevitable restriction that necessitates the progressive evolution of all forces working on our planet. The present formation is the continuation of ancient formations disturbed by similar accidents.

But here I come face to face with an objection about which I must say a word. Some standard treatises will confidently tell of the permanence of the great oceanic basins. Especially will you see in certain works which are in the hands of everyone the statement that the Pacific has always been an ocean.

On what does this theory rest? Almost exclusively on the fact that our geologic strata contain no deposits in which can be clearly identified any formations from great depths; for I do not consider as a valid argument the fact that the outline of the Pacific coasts seems formerly to have been marked by channels where coursed the marine floods of former ages. The first objection, on the contrary, has its value. In fact, if you asked me to cite a geologic stratum representing a depth of 4,000 to 8,000 meters, I should be much embarrassed to do so, although certain manganese deposits associated with radiolarians have sometimes been considered as belonging to a great depth. But I do not think that this is positive proof and here is the reason. First of all, it will be observed that the land has necessarily much oftener been subjected to movements of slight range, capable of causing emergence from depths of 50 to 100 meters, than to movements great enough to bring beds back to light from hollows of 10,000 meters. These deep hollows stand by themselves and besides must always have constituted exceptional cases. Simple logic therefore leads to the conclusion that the representative deposits in our strata must preferably come from littoral sediments or from slight depth. Abysmal deposits on any hypothesis must therefore be much rarer, unless there is in them a primary difference, a demarcation traced from the first day on the model of our planet. If these abysmal deposits appear to be lacking, that may be explained in two ways without necessarily concluding the indefinite persistence of the great oceanic hollows. It is either because we do not know how to recognize these deposits, transformed as they have been by diagenesis and metamorphism in a movement of the crust which, by its very extent, has here reached the greatest violence, or else because they may have been disintegrated and carried off at the time of this violent emergence.

I recognize that these arguments would be of little value if, on the other hand, all geology did not impress us with the idea that the seas have been constantly displaced on the surface of the earth, and not only such small seas as the Baltic, the North Sea, and the Mediterranean, which are the immediate prolongation of neighboring continents, but even oceans like the Atlantic or the Indian Ocean, where we so naturally picture ancient continents having united Brazil and South Africa, or Madagascar and India, to be later broken up by sinking. These sinkings must have been not merely the counter-equivalent of folded ranges localized along the length of old geosynclines; it is entirely probable that they had as a consequence or as a corollary the removal, at least relative, of other deep terrestrial cavities, left so by the passing out of the waters. In the Pacific likewise the evident dissolving of certain Tertiary deposits, notably in some of the coral islands, proves that the land has moved vertically in a recent epoch.[1]

Oceanography will some day tell us exactly what there is in these hypotheses. Suppose, in fact, that a marine basin had been constantly filled by the sea since its origin (which with few exceptions is entirely possible). We then ought at this point to meet with a sedimentary series complete, without break, extending from the pre-Cambrian to the Quaternary. A sounding deep enough, traversing this series, would give us the ideal geologic section, the integral section, which would render insignificant the finest sections furnished by terrestrial escarpments (such as the Colorado Canyon), on condition, which is uncertain, that the parts of the formation not very deep might not have been entirely despoiled of their organisms and reduced to a clayey residue by diagenesis. Even if the section presented some gaps its study would give us information, in a precise and directly experimental way, on one of the most obscure problems in the history of the globe.

I repeat then, because I know that my opinion on this point is not accepted by all geologists, that as a rule, save in exceptional cases, it does not appear to me necessary to establish a fundamental difference, a permanent difference, between the regions to-day occupied by the seas and those occupied by terra firma. I do not believe that in their entirety, with some possible exceptions to which we shall return, the present oceans, since the beginning of geologic history, have had their sites marked out in advance to be continuously occupied as heretofore by the waters. The difference between the seas and the continents, which forms the most characteristic feature of our physical geography, is to my eyes only a momentary stage in a continuous evolution through all past ages and probably destined to be continued through all ages yet to come.

When one studies geology, the first notion with which it is necessary to familiarize oneself is that of the instability of the seas. One must picture to himself that over the present site of all our continents, almost without exception, the seas have passed during an ancient geologic epoch—at Paris as well as at London or at Vienna. I even believe, and here I conclude this digression, that the greater part of our present seas cover the sites of ancient continents and may mark the place of future continents.

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[1] Robert Douvillé gave in La Nature, 1911, pp. 401–405, a good résumé of the history of the Pacific.

This comparison between oceanic and continental geology presents a very extended program for our study.

In the first place, continental geology includes the study of certain horizontal strata, such as the limestones, sandstones, schists, etc., a study called stratigraphy. Here especially are some formations deposited under the waters of ancient seas which formerly covered our globe. We shall very naturally find again at the bottom of the seas similar deposits in process of formation; the present composition of these marine deposits will enlighten us as to the past of our geologic sediments.

This present sedimentation in the seas is the part of oceanography which has most attracted the attention of geologists; it is likewise the best known phase of our subject and will interest us the longest. It proposes a multitude of questions: on the aspect of the deposits with relation to the topography of the bottom of the seas and on that so convenient hypothesis of horizontal stratification which, according to Sténon, is the basis of our geologic theories; then on the organic and chemical nature of these sediments; on the transformations that they have undergone by diagenesis at the very bottom of the sea. In this regard, especially, the problems that confront us are of peculiar interest. We know from geology that the strata emerged on the continents continue through all ages to undergo transformations which at times end in making them unrecognizable and one of the essential traits of which is the gradual elimination of the organic remains by their transition to a crystalline structure. This is what is called metamorphism or metasomatosis. In the present marine sediments we shall come to see in actual operation phenomena which appear to me very closely to resemble those of metasomatosis and to which is given the name, also a bit barbarous, of diagenesis. These are modifications undergone by marine deposits at the bottom of the seas, consequently before their emergence: modifications which, for chemical reasons as yet not fully determined, seem to end in results very analogous to those of metasomatosis at the surface.

And the geology of the sea bottom will also bring before us that other great branch of geologic formations called igneous rocks. We shall have a word to say about submarine volcanoes.

Finally, no more than does terra firma remain immovable, does the sea escape results of internal movements. There are small, relatively feeble earthquake shocks. There are also the great geologic movements shown by their two principal forms of vertical displacements and foldings. Finally, from some such movements of the crust have come in geologic history those oscillations of the seas of which I was speaking a while ago.

And we shall end by examining how an ancient sea could become dry land, how an ancient continent could become sea. This will lead us definitely to discuss the bottom of the sea as a continent and to attempt that method of mapping which sums up the entire geology of a country, the establishment of submarine geologic charts. You see that this is a very comprehensive program, and one that would fit an entire book rather than a single lecture. If I were to give it the development that it deserves, I should be obliged to appear before you many times. I shall be content, therefore, in this lecture to indicate its most characteristic outlines.

At this point I must confess to you, furthermore, that my task consequently, if not easy, will at least be abridged. The geology of the bottom of the seas, with which I shall try to entertain you, is still very poorly known to us. Interrogation points are presented on all sides and very few of them have been answered. We should not complain too much about this. No doubt what I shall have to say to you here this evening will lack interest. But what is not known remains to be learned. That is the harvest of the future. It is the grain which is springing up. It is the almost unexplored field where one may hope some day to find the key to problems that terrestrial geology elsewhere proposes to us. The search that arouses the fever of discovery is always joyous, when in the great palace of truth, here flooded with light and surrounded by the throng, there already lighted by pale rays and accessible to the rare passers, it perceives some corners now shrouded in dense darkness where in imagination it hopes may presently shine forth marvellous invisible treasures which hardly yet attract the covetous.

Although we know little of the geology of the bottom of the seas, it is almost enough to define it, to comprehend it. Oceanic geology proposes to us, as I have said, for parts of the earth at present again covered by the waters, the same problems that terrestrial geology seeks to solve in regions now emerged. It likewise seeks to know, from one point to another, what the accumulation of sediments is which have been deposited in successive periods of a very old history or which are still being deposited there, to what movements these strata have been subjected, what eruptive rocks have traversed them.

Whether located in the depths of the oceans or placed on our continents, the point of view, from this fact alone, is not different. Now we already often have much difficulty in recognizing the complete and exact geologic history of a place on our continents, the very ones most readily accessible, like Paris, the most furrowed by cuttings and perforated by borings. How much more so when it is necessary to work under water several thousands of meters deep?

Difficult as it may be, however, the problem is not insoluble. Although unfortunately the attention of oceanographers has up to this time been attracted rather by submarine topography, zoology, the physical and chemical study of sea water, and other questions, we begin to possess valuable data concerning the present sediments of ocean bottoms. It may be hoped that some day, instead of limiting the work to the epidermis of these submarine deposits, we shall penetrate them better by deeper and still deeper borings.

The day when we shall energetically attack such investigations, an entire world will be opened to science, without doubt full of unsuspected revelations: a world in which from afar we are beginning to discern the first confused views.

1. PRESENT SEDIMENTATION.

(*a*) SUBMARINE TOPOGRAPHY.

Let us pause for a moment and view the manner in which the sediments are deposited at the bottom of the present seas. Here first of all comes in submarine topography, of which we are beginning to have a fairly approximate idea. It has frequently been observed that this topography differs from that of the continents in the fact that a fine dust is constantly falling there, and being but slightly influenced by the currents, though agitated in shallow water, is accumulated there by gravity alone, filling little by little the hollows and tending toward a gradual leveling. It has been observed in this connection that one could go in a carriage from Brest to New York over the sea bottom without having any definite notion of slopes.

This relative horizontality of sea bottoms, from which as a matter of course we must exclude the shores, has geologic importance; it is in fact, the point of departure of a convenient hypothesis, which, according to Sténon, dominates our geology—that of horizontal sediments superposed in the order of their formation and having taken their present slopes only through some later orogenetic or mountain-making movements. It is obvious, however, that this is a mere approximation; and when one finds along the western coast of America some abysses of 4,000 to 5,000 meters depth immediately succeeding ranges of the same relief; when to the south of the Aleutian Islands or to the east of Japan, to the east of the Tonga Islands (north of New Zealand), to the east of Australia, and elsewhere, one falls abruptly into these gulfs, attaining in one case a depth of 9,700 meters, in the presence of slopes estimated at more than 10 kilometers in 200 to 300 kilometers of breadth—it is no longer a question of gentle slopes. It is the same as regards the holes in the Caribbean Sea 5,200 meters deep, or on a smaller scale, those of 3,000 meters found 15 kilometers south of Crete, or in an opposite case, as regards the chain of isles rising in the midst of the Pacific like summits of a submerged mountain range. It may be said on the subject of sedimentation, however, that on steep slopes, deposits must hold so insecurely that sediments comparatively thin must have a tendency toward presumed horizontality.

To limit ourselves to two principal examples, the topography of the Atlantic is rather simply characterized by two deep zones extending north and south that indent a plateau surmounted by volcanic cones. In the Pacific, there are first of all, along the coast, some deep hollows corresponding with the folded ranges of the shores. But there is also a long series of hollows extending in an east and west direction from China toward the Gulf of Mexico, and, in the south there is a north and south hollow at right angles to the preceding which passes to the east of New Zealand, a hollow consequently having a direction like that of the American continent or of the Atlantic Ocean. These accidents well indicate the complexity of the topography of this ocean, which has sometimes been inaccurately plotted, and they imply a very complex ensemble of folds pertaining to various ages, with vertical subsidences, just as on the continents.

The horizontal aspect of the nonlittoral sediments should be considered only as a tendency accentuated with time by the very effect of some of the first deposits under which the inequalities of the bottom have been leveled. It has sometimes been held that when the sea has invaded a continent it has been preceded by what has been called a marine abrasion. And, in fact, it is possible, when the movement is made slowly after a period of emergence which has caused a peneplain, that this kind of tide has almost invariably displaced horizontal sediments. It could not have been the same wherever the vertical displacement was a sudden matter nor wherever the invasion of the sea was the result of a folding in a geosynclinal zone. If we come back to the present epoch, there is every evidence that strictly contemporaneous sediments are being produced to-day, some at 8,000 meters and more in depth, others but a few meters below the level of the waters. Let us, then, exclude the abysmal hollows, for we have seen that they lengthen the discussion. Certainly the level of contemporaneous sediments similar to those of geologic periods may differ according to location by some 2,000 meters. One sees, therefore, how inexact it is to prejudge the general horizontality of sediments pertaining to the same ancient epoch.

(*b*) VARIABLE NATURE OF SEDIMENTS, AND DIAGENESIS.

What is now going on in the bottom of the ocean? I mean, what is going on there in the very special order of geologic ideas? The first thing that interests us is that sediments are being deposited there and that their nature differs according to the depth of the water, the distance from continents, the direction of currents, the temperature of surface waters, etc. Starting with our geologic strata, we shall thus be permitted to discover under what conditions analogous sediments have formerly been deposited. For the exploration of oceanic deposits, we are provided with well-known instruments called the sounding dredge or the Buchanan tube.

In the formation of these sediments a first important demarcation must be established. Some are the product of the mechanical destruction of continents. These are clastic débris removed from the rocks and the soils of parts emerged, and after having been rolled around for a time, and for a longer or shorter period held in suspension, they are at last deposited. These are terrigenous deposits. Others have begun by being in solution, but all have a like origin, and they separate from these solutions, either by the medium of organisms, or by a simple chemical reaction. Finally, other chemical reactions, characterized as diagenesis, continue in the sediments after their deposition.

The terrigenous deposits proper form a crown or belt around the continents. These cease at a distance from the continents and are followed by sediments entirely different in character, either those of organic origin, resembling a grayish ooze, which we shall presently distinguish, or those of chemical origin which may take on the appearance of red clays. This distinction of terrigenous deposits is very important, although one must not attribute to them, as is sometimes done, a too absolute value, for, correctly speaking, there are hardly any sediments which do not include some terrigenous elements. Far distant from the coasts, however, these terrigenous elements are generally reduced to very fine particles which remain in suspension much longer than is generally believed and which contribute toward the clay of the deep ooze, at the same time that this clay, redissolved, as we shall see, yields the silica of siliceous organisms and consequently contributes to the formation of silex in the strata. When instead of confining oneself to a summary statement, an examination is made of certain sections of samples from very deep soundings, one often notes these irregular intercalations of extremely fine, true sandy beds[1] which indicate a dragging along of these particles by the waters to very considerable distances.

These detrital sediments, as I have just said, come from continents; they are the direct product of erosion. Now, this erosion is important. It is estimated that under present conditions it would destroy the land in 7,000,000 years; each year the ocean receives 10 cubic kilometers of solid material, composed in great part of silica and alumina.[2]

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[1] Expedition of the "Gauss" and works of Thoulet.

[2] The average composition of the terrestrial crust in round numbers is 60 per cent silica, 15 per cent alumina, 6 per cent iron, 5 per cent lime, 5 per cent alkalies. (See Science géologique, p. 654.)

These detrital materials are subject to mechanical action which is especially visible along our shores and which contributes to the formation of littoral strata so abundant in our geologic periods. At the same time the river waters carry along to the sea chemical products of every nature which are going to meet in this general outlet and which gradually increases not only the salinity but also the content of various chemical substances, reserves on which we shall see the organisms drawing.

Terrigenous muds are divided into (1) blue muds charged with sulphate of iron and permeated with ammonia salts; (2) red muds in which the iron is a peroxide; (3) green muds in which the iron is in the state of silicate (glauconite). These last skirt the length of the coasts. The facts under discussion are so well known that it is enough to recall their nature and I shall limit myself to some brief ideas on the distribution of organisms in marine deposits, a very important but also very common phase of my subject.[1]

Marine beds, you know, comprise a primary grand division called the continental plateau, terminated by the line of 200 meters depth and characterized by the penetration of luminous rays under such conditions that plants can live there, permitting the existence of herbivorous animals. Certain seas, like the North Sea or the Channel, belong entirely to this continental plateau. Two principal zones are here easily distinguished, the littoral and the sublittoral, which are subject to the play of the tides, and where the individuals, of a limited number of species, are very abundant. The summit of the littoral zone is characterized by the level of the Balanes; then deepening, there are the Mytilus, the Littorina, the Patella; and finally, in the zone exposed only at the low tides of the equinox, the Haliotis and the Pecten. After these come next, from the level of low tide down to about 27 meters, the zone of the Laminaria with the oyster beds, the cuttle-fish, and the calamarians. Let us note, incidentally, that at this level the algæ help to fix and to isolate two constituent elements of sea water, iodine and bromine, which are extracted therefrom.

Lower down, from 27 to 92 meters, we have a zone which comprises the important fishery regions frequented by the cod, plaice, turbot, and sole. Finally we come to the continental plateau, where, under very special conditions, are found the coral formations, which play a part so important in the formation of geologic strata. As regards coral the most important thing for us to remember is that coral organisms live only in very pure water where the surface temperature does not fall below 20° and where the variation does not exceed 6°; in fact, at a depth which, according to recent measurements, does not exceed 64 meters for true corals and 120 meters for calcareous algæ of the group of millipores. On account of these very close restrictions the coral reefs of to-day occupy a much localized zone in the vicinity of the equator; and the fact that in the oldest geologic periods corals extended into the polar regions is of great importance in the history of ancient climates.

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[1] See a very good résumé of this question in Collet's "Les fonds marins."

These corals present opportunity for another curious observation. Darwin, after some very hasty observations, advanced a theory accepted by Dana, according to which the construction of coral reefs demonstrated a gradual sinking of corresponding regions. According to the theory of Murray, now admitted, the coral reefs simply mark out submarine volcanic cones, such as exist in great number in the Pacific. Some such cones have been recognized by oceanographers. The *Nero* pointed out 20 of them on a cable route between Japan and Hawaii, one rising to within 150 meters of the surface, others reaching from a depth of 9,000 meters up to 1,200 meters below sea level, etc. It is on these cones that organic sediments at first accumulated (and that since what may be a very ancient geologic epoch), down to the day when coral organisms from the deep, such as the Lithothamnium, begin to be established there and approach the surface at the rate of 50 meters in a thousand years. In fact, and rather paradoxically, the corals often play only an accessory rôle in the construction of so-called coralline reefs, certain of which present scarcely anything except calcareous algæ. Then intervene the remains of these calcareous elements and the accumulations of various organisms which become established on the reef.

We come finally to sediments of the deeper seas. These are composed chiefly of organisms which are divided into two principal categories—(*a*) calcareous deposits with globigerina or with pteropods; (*b*) siliceous deposits with radiolarians and diatoms.

The influence of temperature on the distribution of these organisms is very marked. In warm waters the calcareous organisms dominate; in cold waters only the siliceous organisms exist, and it thus appears how both of them procure the elements of their substance.

As for lime, which is in fairly appreciable amounts in sea water, there are no traces of carbonate concerned, but the sulphates are much more developed. Those are transformed by carbonate of ammonia coming from the organisms, and the carbonate of lime is then secreted. As the decomposition of nitrogenous matter is especially rapid in warm waters, these reactions are there favored. The calcareous secretion, abundant in regions of uniformly high temperature, diminishes in temperate regions where its maximum takes place in summer, and nearly disappears in the polar zones.

Thus the calcareous organisms, the globigerina, play a rôle entirely dominant. Nearly all the sea bottom contains at least 10 per cent of it, but the name globigerina ooze is reserved for cases where the proportion exceeds 30 per cent. These globigerina oozes contain a little less than 2 per cent of siliceous organisms and a certain proportion of clay, which tends to be increased by the dissolving of limestone in diagenesis. Finally the globigerina ooze becomes a red clay.

A map of the marine beds reveals the predominant rôle of these globigerina oozes, except in the Pacific, where the latest explorations of the *Albatross* have, however, found some zones of considerable extent. More locally at a maximum depth of 3,000 meters some pteropod oozes are found, which are indicated on the map of the Atlantic.

Let us pass now to the siliceous oozes. Here the origin of the silica is the clay which exists in fine suspension down into the extreme depths. It is supposed that the chemical medium is furnished by decomposing organic matter which reduces the sulphates to alkaline sulphides, after which the latter in their turn act on the clay. Experiments by Murray and Irvine have shown that in order to sustain life in diatoms in a liquid there must be a supply of pulverized clay.

Now, the quantity of clayey material remaining in suspension increases in proportion as the temperature of the water decreases. This is without doubt one of the reasons why siliceous diatoms are particularly abundant in cold water. But this phenomenon is complex and the observation should not be generalized upon.

The siliceous organisms comprise sponges, diatoms, and radiolarians. Only the last form in the sea distinctive deposits. The others remain in a state of balance in the calcareous deposits. Sponges have a very extended area of dispersion because their embryos swim freely and their spicules are found in the most diverse strata. They are quickly dissolved and help to keep the silica in motion. Diatoms, siliceous algæ, live in waters of weak salinity, such as estuaries. Immense floating banks of them are met with in the Atlantic many kilometers long and several meters deep. They are developed like calcareous algæ in the upper layers of water, where they serve as food for numerous marine animals, after which their débris falls to the bottom. An extensive train of them is found in the Antarctic Ocean, another to the south of Bering Strait. And, furthermore, contrary to what was claimed some years ago, the *Albatross* observed them in a warm region in latitude 12° south on the coast of South America. The radiolarians live chiefly in warm and relatively quiet waters. Their deposits form an equatorial track across the Pacific from the Gulf of Mexico toward Australia, then between Australia and Java. In places in the Pacific the siliceous organisms dominate in the ooze; but it is chiefly in the Antarctic Seas that they come strongly into consideration, attaining 16 per cent.

We have just indicated the distribution of these various oozes. Let us see how they are formed and what they become.

First of all we note the influence of surface currents, which according to their temperature develop more or less organized life of this or that character. Along warm currents the surface organism descends into the sea, serving to nourish other life deeper down which in turn descends still lower. On the surface borders of these currents the variations of temperature sometimes produce great slaughter. Finally there is formed near the bottom a slow chute of organic particles, some calcareous, others siliceous.

These particles before reaching the bottom certainly undergo partial dissolution and some chemical reactions, the more accentuated as they take more time to descend. This is the beginning of the transformations that we call diagenesis. Some of the above-mentioned differences between deposits of various depths arise from this. Thus the fragile shells of pteropods are usually dissolved before reaching a depth of 3,000 meters and for that reason they are not found deeper down. The globigerina have greater resistance, but end by disappearing in their turn in the great depths. This is why in the Pacific, deeper than the Atlantic, so few of them are found at great depths, although they may be abundant at the surface.

Once deposited at the sea bottom the oozes continue to undergo like transformations which must gradually give a different aspect to like deposits according to their age of formation, or, when these deposits have later been brought back to daylight in geologic ages, according to the duration of their sojourn in the sea.

These reactions are not yet well known. Chemically there would be opportunity here to study what effect may be produced in oozes of various compositions by sea water at about 2° of temperature and at the great pressure there.

In reviewing some of the observations made on this subject I am struck by the apparently close analogy between these phenomena and those which characterize the superficial alterations of our strata in the line of peroxidation, directly exposed to waters strongly aërated and charged with carbonic acid. Some very different conditions lead to the same result. The first fact, for example, is the elimination of lime, decalcification. We have already remarked that the deeper the ocean bottom the less do calcareous shells appear there, hence at great depths we find manganiferous red clay like that which decalcification and lateritization produce on our plateaus. The *Gauss* expedition at the center of the Atlantic brought up some soundings in which there was clearly less lime at the bottom than at the top. Some have believed in a modification in the conditions of deposition; I would rather believe in a later alteration. At the same time, however, as at the surface, the proportion of magnesia increases because the bicarbonate of magnesia and of lime is less soluble than the carbonate of lime: there is dolomitization.

On the other hand, there is produced at centers of attraction, exactly as at our horizon, a concentration of silica and other accessory bodies to which I shall presently revert, such as iron, manganese, and phosphate of lime. It is very probable that many similar concentrations observed in our geologic strata date from the epoch when the sediments in question were still under the sea, although the phenomena may undoubtedly have been continued and accentuated after emergence. Among the phenomena of dissolution one may still observe that on the great marine bottoms where the sharks' teeth and the tympanum drums of whales are at times rather abundant, all other parts of their skeletons have been dissolved; generally all that was phosphate of lime has been eliminated, the calcareous parts having the greater resistance.

Once dissolved, the substances tend to recrystallize. Calcite, for example, will refill all the empty spaces, notably those left by the dissolution of the skeleton or of the shell, which is thus replaced by a substituted shell with crystallographic orientation.

Likewise in malm rock, the silica arises from the spicules of the sponges and is reprecipitated in the form of silica globules for example, in the interior of the foraminifera, etc.

One of the most important of the oceanographic formations which must be connected with diagenesis is that of the red clays with deposits of manganese.

Red clay was found for the first time by the *Challenger* at a depth of 5,000 meters, and Wyville Thomson considered it a residue of the globigerina ooze. The accepted theory is otherwise, and according to Murray this red clay is ordinarily attributed to the decomposition of various rocks, especially the volcanic rocks which form the marine bottom.

Perhaps this would be the place to review, in a way, the explanation of Thomson and to say that in the very great depths everything is transformed into red clay because everything calcareous is dissolved before reaching there. Thus at the surface of continents we see red clays of slightly varied compositions,[1] with more or less silica associated with the alumina, produced as well on the calcareous plateaus, in the so-called pockets of siliceous clay, as on the serpentines of New Caledonia or on the ancient plateaus of Madagascar.

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[1] See Gîtes métal., vol. I, p. 197, on lateritization.

The red clay of the seas is formed essentially of brick red silicate of alumina, with a tint of chocolate brown, or even blackish, due to the more or less marked development of manganese.

This development of manganese often in large nodules, constitutes a comparison besides with surface formations where I have shown how characteristic and abundant it is.[1] The manganese of the red clays, which has too exclusively been connected with volcanic rocks, really comes from all kinds of eroded rocks in which the feeblest manganiferous traces occur in the remarkable process of its concentration.

The hydrated silicate of alumina which is the characteristic element of these red clays is accompanied by zeolites, by small fragments of pumice or by volcanic crystals (in the Pacific with millions of sharks' teeth, the tympanum bones of whales, etc.). It would be interesting to point out the quantitative differences that these various clays present which must pertain to their origin. On the average, in the analyses of the *Challenger* the quantity of iron was more than that of alumina. There is often a proportion of silica too great for the theoretic composition of silicate of alumina; the silica, due no doubt to the precipitation of siliceous organisms, not yet being transformed. Likewise, the proportion of carbonate of lime always remains very great, up to 23 per cent in a *Challenger* specimen, from a depth of 4,207 meters. Carbonate of magnesia reaches 3.24 per cent, and results, no doubt, from a concentration similar to that produced on the coral reefs.

(*c*) FORMATION OF PHOSPHATES AND FERRUGINOUS SEDIMENTS.

We come now to study the ordinary and common deposits which constitute the great mass of sediments. There are, however, some rarer deposits more exceptional, which may be of practical interest to us. They are those composed of utilizable accumulations of mineral wealth, the relative commercial value of which depends on whether its elements have been brought together there in an abnormal manner. The sea, which I have elsewhere called the universal drain, holds some traces of all chemical bodies, including gold, which is found there in quantities not at all negligible. This or that circumstance may cause the concentration of one of these elements and from it form a true ore. I shall be content to examine, as examples, two bodies, phosphate of lime and iron, having already said a word about manganese.

Let us first take the phosphates. If a direct examination be made of the phosphates of our geologic strata without first having recourse to a comparison with oceanography one finds that phosphate of lime, very abundantly, one might say very generally, scattered through the greater part of our sediments, as it is in the state of apatite in most of our rocks, is condensed in exceptional quantities in certain deposits which appear in a general way, as M. Cayeux observed in 1897, to correspond to some disturbances of equilibrium causing an advance, or more rarely a withdrawal of the sea; a phenomenon in which it is probable that numerous living things were killed by changes of temperature resulting from a modification in the currents, and consequently are accumulated at the bottom of the sea. Phosphate, which existed at first in solution in sea water, has passed through the medium of organisms; and its greater or less abundance is in accord with that of these organisms themselves, save that they later have undergone some more or less pronounced concentrations: in the sea itself by diagenesis or, after emergence, by metasomatosis.[1]

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[1] Gîtes métal., vol. 1, p. 200, and vol. 2, pp. 530-536.

This is the general theory that oceanography demonstrates for us. The *Challenger* expedition has already brought up from the depths rather numerous phosphatic concentrations. These concretions were encountered especially on what is called Agulhas Bank to the south of Cape of Good Hope, where the German expeditions in the *Gazelle* and the *Valdivia* again found them later, then on the east coast of Japan, at the junction of the warm Kuroshimo with the cold current of the Bering Sea, on the Atlantic coast of North America, in the straits of Florida, etc. The corresponding depths of water do not exceed 1,000 meters and are often less than 200. It may follow from this, that in the greater depths the precipitated phosphate of organisms is dissolved before reaching the bottom.

When on a general map of the oceans you mark these localities of phosphatic concretions you note that they are specially present at the points where warm currents encountering a cold current produce decided variations of temperature in the surface water. You know how sensible marine organisms are to variations of this kind. It is therefore probable that organisms thus killed are accumulated at the bottom of the sea at the corresponding points and have there furnished the phosphate. These organisms should be especially invertebrates; but there must be added some fishes, the teeth of which abound in certain phosphatic chalks. The constant association of carbonaceous material with geologic phosphates equally proves this organic origin. Along the American coast, for example, a conflict is produced between the cold Labrador current and the warm waters of the Gulf Stream. According to the severity of the polar winter, the cold current encroaches more or less on the warm stream. It was so in 1882 when in the Atlantic Ocean off the coast of New England there appeared, over a width of 270 kilometers, beds of dead tilefish to a depth of 1.8 meters. On the other hand a general displacement of the seas and especially a transgression on the continents must have been a particularly active cause of changes in the course of ocean currents and consequently of similar destructions.

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[1] See, on this subject, my Traité des gîtes métallifères, vol. 1, pp. 646-649, 659-661.

This is one of the reasons, as I have elsewhere stated, why each great period of folding has been followed by a phase of phosphatic deposition, just as we find after it, from somewhat different though mutual causes, oil-bearing hydrocarbon deposits, saline deposits, and deposits of iron.

If we revert to the phosphates, the greatest concretion which has been dredged up came from Agulhas Bank, where there are some genuine greensands (glauconitic) in the phosphates similar to those of the upper Cretaceous; it measured 23 by 16 by 12 centimeters. Oftener these nodules, like those found in geologic strata, as in the Gault or the Liassic, are less than 10 centimeters. Their form is similar, being irregular, the contours at times rounded, sometimes angular and with an outer deposit which is at times dark and shiny when the phosphate existed in the ooze, at other times gray and dull when this phosphate leaving the ooze was covered over with organisms, such as bryozoans, corals, sponges, and foraminifera. The nodule itself is often covered with shells of lamellibranchs, brachiopods, and gasteropods, more or less completely phosphatized, as so often occurs with geologic phosphates; we also find in it particles of calcite, of glauconite, and of detrital minerals. The relative proportion of shells fixes the relative amount of carbonate of lime it contains.

Finally, you observe, in these present phosphatic nodules, a fact which is constant in the geologic strata; that is, the transition into true iron ores through the medium of the glauconite. The nodules are often yellowed or browned by peroxide of iron due to a decomposition of the glauconite like that which we shall see taking place in the formation of true iron ores, and, like that, curiously similar to the phenomena produced in the superficial continental reactions above the hydrostatic level, in what is called the zone of peroxidation. Potash, a soluble element which plays an important rôle in glauconite, is eliminated as it may become exposed and that is why the iron is peroxidized.

This is a case of what I have above called diagenesis; but other cases exist which apply more directly to the phosphates. In a chalky ooze of phosphatic elements, one can readily ascertain that the phosphate is gradually concentrated and concreted around nuclei already phosphatized, like that produced in the growth of all crystals, or likewise by pseudomorphism, on some simple calcareous elements. This concentration began beneath the sea—it is diagenesis; it continued by metasomatosis after the emergence of the phosphates to their present levels, and it has thus played an enormous rôle in the formation of utilizable lodes as they are presented to us. The soluble phosphate which appears to be at first in the state of phosphate of ammonium, but which may also be in the state of alkaline phosphates or of phosphate of calcium, gradually impregnates the adjacent strata, especially those that are calcareous (polyps, corals, etc.), and sometimes even the clay, and becomes substituted for them, tending, through a correlative attraction exercised on fluorine, to take the composition of apatite, which is a crystallized fluo-phosphate of lime.

The study of ferruginous sediments offers like data for very interesting oceanographic observations on the interpretation of our iron ores.

In the present marine deposits, independent of sublittoral oozes, we find iron either in the form of glauconite, or as red clay, each of these formations corresponding to a different origin and conditions.

Glauconite of the present seas is a silicate of iron and potassium which chiefly characterizes some terrigenous deposits, particularly the muds and greensands. It is found along the continents, at a depth not exceeding 2,000 meters, but only where the terrigenous sedimentation is slow, without heavy fluvial supplies and where, consequently, the phenomena of solution and reprecipitation have time to act. It is evident that the iron of this mineral comes from the rocks and strata remolded by the sea, as its potash has for its origin the feldspars and potassium micas. For the alumino-alkaline silicates which chiefly characterize all our rocks is substituted a ferro-alkaline silicate, the alumina separating out from the other part as clay, to enter presently in the composition of the chlorites. This substitution is one of the first essential effects of the solvent reactions exerted by sea water, and we may at once note that lake water is powerless to produce a like chemical transformation. There is no glauconite in lake waters, probably because the iron in these waters is readily dissolved by the organic acids and immediately peroxidized by the excess of oxygen in them, being brought to precipitation under various forms, the most characteristic of which is bog iron, or limonite, instead of combining with the silica. Glauconite has a certain tendency to form small nodular grains not exceeding one-tenth of a millimeter. I have just remarked that it is frequently associated with phosphate, and like this has a tendency to develop by epigenesis, for example, from grains of feldspar. Like silica, the rôle of which is very similar, glauconite becomes solidified first on porous objects which have contained eliminated organic matter, such as the pores of foraminifera, or in the thin fissures of minerals. Then begin in the still submarine deposit renewed movements, some of which, purely mechanical, accumulate the grains of glauconite at certain points by levigation such as has taken place in the tufas, and other movements, of chemical origin, result in the gradual concentration of iron.

When ferruginous elements under whatever form once exist in a stratum, they do not remain there unchangeable. The glauconite is altered, turns green, yellow, red. At the same time iron permeates neighboring oozes where it acts on the calcareous elements. There is then a transition to siderite, which itself may later be transformed into chlorite, then into hematite.

These phenomena, begun beneath the sea and compelled from that time to form true ferruginous deposits, are continued, as we have seen in the case of the phosphates, in exterior alterations (by geologic processes) with gradual enrichment in iron because of the elimination of the more soluble calcareous elements which at first accompany them. You have then, at last, either some hematite, if alumina was lacking at the outset as is the case except when the glauconite is already associated with a calcareous ooze; or, when the point of departure was direct, an alumino-ferric silicate complex, like that ordinarily presented in our rocks, a red clay, retaining alumina associated with iron. The red clay and the iron ore proper may have, as can be readily understood, easy transitions from one to the other.

This study, as you see, throws a certain, though imperfect light on the important practical question of our sedimentary iron ores. And I would have you observe apropos, in passing, how pure science, science totally disinterested, which seems to have for its object only the search for truth, often has some useful results.

It could not be foreseen that dredgings undertaken at the bottom of the sea would enlighten us on the origin of the ores of iron or manganese, and enable us, consequently, better to establish the theory of their formation, and finally to lead to borings at a great depth permitting the development, under conditions at first unforeseen, of an immense reservoir of iron like that which at this moment is making the fortune of Normandy.[1]

2. MOVEMENTS OF THE BOTTOM OF THE SEAS—SUBMARINE VOLCANOES.

The movements of marine bottoms are of two kinds. You might here see the slow displacements to which certain observations on our shores bear witness, or the deep subsidences of which geologic history offers us numerous examples. I could tell you of the cities of Ys and of those avenues of statues which on certain islands of the Pacific must have led in days of yore to some temple to-day engulfed beneath the sea. Not to bore you, I will confine myself, however, to some brief observations on volcanic phenomena.

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[1] We could profitably discuss many other questions, particularly the intervention of glaciers in sedimentation, of which I wrote in La Nature, Oct. 5, 1912.

The ancients attributed the birth of all the islands in the Archipelago to a sudden upheaval in which the gods intervened, and likewise they thought that the islands could be engulfed by the anger of Poseidon. Although the origin of most of the large islands may have been entirely different, the ancients were not so far wrong as to their own region, for the history of Santorin, and of the famous island of Julia, are classic examples of like phenomena. The island of Julia appeared in 1831 between Sicily and Pantellaria. There were first some shocks; then, 15 days after, a column of water and smoke rose 25 meters high; a little later there was a column of 500 meters; finally there appeared an isle 4 meters high in the form of a crater, while the sea around was covered with dead fishes. In 5 days it rose from 4 meters to 20 meters, and a month after the first movement the island attained 1,600 meters in diameter. Six months later it was engulfed. It reappeared in 1863 to be swallowed up again. There were similar phenomena seen at Santorin in 1866, at the Azores, near San Miguel Island, in the Tonga Archipelago, and elsewhere. Saint Paul Island is a known example of an extinct volcanic crater which rises from the sea and which the sea invades.

In other cases, submarine cables have been found with the gutta-percha covering completely melted.

Marine movements of internal origin are of two kinds.[1] There are first of all earthquakes properly so called, as their center of action may be on land or sea. Their principal effect as to land is the propagation of a vibratory wave, but with a regularity and a uniformity maintaining a mean, which are lacking on our continents. When a vessel is subjected to these earthquakes at sea there is the impression of its touching the bottom, without, however, suffering damage, and there is astonishment at not seeing the ocean foam on the reefs. Reaching the shore, the undulation produces tidal waves which may have been evident on the coast of Cornwall and on that of Brittany, but which are transformed into cataclysms on the shores of Japan and Sumatra, some of which, called *tsunamis*, have caused the death of 30,000 to 200,000 persons. Other phenomena of volcanic origin have for their principal manifestation a projection of water to a great height, like that produced by a submarine explosion. Elevations of temperature are likewise observed in the deep beds, and sometimes fish seem thrown out like flying fish and cover the sea with their bodies. The region noted by Daussy, in the middle of the Atlantic, at the equator, is a well-known center for these phenomena.[2]

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[1] See Montessus de Ballore, La Science sismologique, p. 182 et seq.

[2] See 1838, Daussy: Note sur l'existence probable d'un volcan sous-marin (C. R. Ac. Sc., t. 6, p. 512).—. 1858, Muller: Report on the facts and theory of earthquake phenomena (Rep. Brit. Ass., p. 20 et seq.; with chart representing the zone of Daussy). — 1887 to 1897, Rudolph: Ueber Marine Erdbeben und Eruptionen (Beitr. z. Geoph. her. von Gerland, 1887 pp. 133–165; 1894, pp. 537–666; 1897, pp. 273–336).

3. GEOLOGIC MAP OF THE BOTTOM OF THE SEAS.

I come finally to the last problem, which, in spite of its great interest, will not detain me long, for its solution is yet hardly outlined—to prepare a geologic map of the bottom of the seas, and, by means of that, to reconstruct the history of the oceans as one may do for the continents.

What I have already said on the present accumulation of marine sediments explains how a Buchanan sounding tube lowered to the bottom of the sea does not as a rule penetrate beyond the recently formed ooze and consequently gives no information on the geologic substratum.

The exceptions are few. Let us limit ourselves to the mention of some excavations whose passages have penetrated a slight distance under the seas—for example, those in Brittany. The only place where work of this kind has been done methodically is at Pas-de-Calais, the geologic map of which has been very nearly completed in view of the proposed tunnel.[1] But the Pas-de-Calais, for an oceanographer or a geologist, is hardly a sea. Its depth is so slight (a maximum of 60 meters between Dover and Sangatte) that it must be likened to a submarine valley across which the sedimentary formations are prolonged very perceptibly from one shore to the other.[2] At the beginning of the Pleistocene epoch communication between England and the Continent could still be had on foot. That is why this region offered a good field for soundings which in 1875 and 1876 gave us more than 3,000 profitable throws of the sounding lead. Thanks to these data a complete map could be drawn, showing the bendings of successive strata from the Senonian in the north to beyond the lower Cretaceous in the south. These soundings have shown that under the fissured and permeable Cenomanian and Senonian chalks there existed in the Cenomanian some impermeable argillaceous beds. On the condition that the tunnel be kept in this Cenomanian bed, or 130 meters below the sea at the lowest point, it could be easily constructed. You know that this project has recently become again a live topic.

Aside from this very special place, we have very few items to glean.[3] However, at various points on the Channel, at Berck, at St. Aubin (Calvados), again at Roscoff, there have been found some Eocene fossils, especially nummulites, proving that at the beginning of the Tertiary epoch the sea had already passed the length of the French coast and had there left some deposits. Farther on, toward England, off Plymouth, some dredgings made in the open sea have brought up some Cretaceous blocks, showing that marine crustacea might have existed between the two important peninsulas of Cornwall and Brittany, and consequently justifying the inference that since the Cretaceous epoch this might have been the site of a marine furrow. The same series of dredgings enables us to trace on the map, from Morlaix to Plymouth, after these Eocene and Cretaceous epochs, some successive zones of Liassic, then of Triassic, with ancient strata in the vicinity of the continent. Thus a series of ancient seas might have existed on the site of the Channel to lead, probably during the beginning of the Pleistocene, to an emergence during which the Channel must have played the part of a continental valley and finally resulted in a last submergence of which we see the effects.

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[1] See La Nature, Apr. 21, 1906, and Revue des Deux-Mondes, October, 1913.

[2] The currents which sweep the bottom prevent the present sediments from being deposited there and facilitate the work of the geologist.

[3] See a work by Paul Lemoine in les Annales de Geographie of November, 1912.

On the Atlantic coast we have but little information in regard to the continental shelf or plateau to the west of Ireland, where the zones of strata which become visible on the continent appear to be prolonged under the sea. In the Atlantic Ocean itself volcanic rocks are found at various points denoting high bottoms not covered over with sediments. Notably, 900 kilometers north of the Azores, at a depth of 3,000 meters, some jagged flows of lava have been found which were almost certainly solidified in the air.[1]

Everywhere else we are awaiting information not yet furnished us by oceanographic soundings, and in order to reconstruct the history of the ancient seas we are reduced to deductions based on the continuity of geologic zones, on the nature of the faunas and the floras in various epochs, and on the relations between these faunas and floras.

In brief, we are led thus to conceive the various types of seas: (1) The type of continental shelf or plateau prolonging the neighboring continents in a gentle slope, which the faint movements of equilibrium may alternately move again above or below the sea (the North Sea, the Baltic, Hudson Bay), etc.; (2) the type of geosynclinal depression in connection with foldings which take at first the aspect of a marine furrow or ridge, to give place some day to a high alpine chain and on which, in proportion to its fragility, become accumulated volcanic and seismic irregularities (Mediterranean); (3) the Atlantic type, where successive subsidences through irregularities of unequal depth extending north and south have abruptly sliced off geologic zones of nearly perpendicular direction, and where the slopes cross these perpendicular zones without the least account being taken of them, a recent ocean at its central axis elevated with volcanic manifestations;[2] and, finally, (4) the Pacific type in which geosynclinal troughs with ranges of folding warp an immense block, or an assemblage of blocks, deeply and unequally hollowed out, with folded ranges welded to solid arch stones, and on the summits of these folded ranges wreaths of islands outlining arabesques.

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[1] Pruvot and Robert studied in 1897 near Cap de Creus (Arch. zool. expér. et génér., pp. 497-510) a submarine deposit of shells anterior to the second half of the Pleistocene, at the beginning of which the present régime was established in the Mediterranean and the Septentrional mollusks had disappeared.

[2] See on this subject la Science géologique, p. 253.

In conclusion, after having seen what is at present occurring in the sea, and having shown by comparison how this study of the present sea yields information on the story of the ancient seas, we are led to ask ourselves whether this same story will go on indefinitely, whether the seas will continue to be displaced on the surface of the globe.

I do not think the seas can ever be lacking on the earth, at least not until the day when the earth becomes only an extinct and frozen globe. It does not seem to me, in fact, that the loss in water could be very great at the surface. Granting that to a certain depth there surely do not exist empty cavities in which this water could be engulfed, it can disappear only through chemical reaction by yielding its oxygen to the oxidation of rocks, while the hydrogen escapes into the heights of the atmosphere. Such a reaction as that certainly does take place. The land exhales hydrogen, and toward a height of 70 to 80 kilometers this hydrogen takes the place of nitrogen. But this is a much restricted phenomenon compared with the immense volume of the seas which, if spread all over the earth, would form a mantle of water 3 kilometers thick, and which even now cover three-quarters of the land. The oxidations, to be effectual, must become more and more limited by the fact that the region of the crust where they act could not exceed 60 kilometers. On the contrary, it is even very possible that volcanism and certain thermal springs may furnish at the surface some new water, fresh, never having seen the light. I believe, then, in conclusion, that the total volume of the seas, which must, no doubt, have been diminishing since the beginning of geologic time, at the same time that their salinity was increasing and as their average temperature has been reduced, might diminish still more. You will see the same phenomena continued, but they will without doubt be retarded more and more in such a way that the cooling of the sun, which will lead to the death of the earth, will probably have had time to be completed before these seas have disappeared.

RECENT OCEANOGRAPHIC RESEARCHES.[1]

By Ch. Gravier, Sc. D.

I.

From cruises far and wide across the seas, especially during the nineteenth century, sailors and travelers brought back large collections of many varieties of animals and plants. To the explorations by Dumont d'Urville, du Petit-Thouars, Péron and Lesueur, Quoy and Gaimard, Hombron and Jacquinot, and others, the Muséum d'Histoire Naturelle owes the great number of original types which make up its rich collections. The marine organisms collected by them were taken, for the most part at least, either between tides or in surface waters, without special appliances.

The cruise of the *Challenger* around the world (1873–1876) marks an important date in this class of scientific explorations. Not content with the accumulation of a mass of material for zoological study, they also made observations on the conditions of the environment in which the captured animals lived. The nature of the sea bottoms was studied; the depths and the temperatures of the sea waters along the course were recorded. This was the beginning of a new branch of the science of oceanography, which has in the years succeeding undergone great development.

This was also the beginning of a series of explorations conceived in the same spirit and undertaken by different countries: The *Travailleur* and the *Talisman* in France, the *National* and the *Valdivia* in Germany, the *Siboga* in Holland, the *Investigator* in India, the *Blake* and the *Albatross* in the United States, and others, without taking into account the numerous expeditions which traversed the Arctic Seas and those which penetrated the Antarctic Ocean.

Special mention is due the cruises of the Prince of Monaco in the Atlantic Ocean and in the region of Spitzbergen.

II.

It is, however, only at a very recent date that the methods of oceanographic investigation have been fixed and systematized. It was, to be exact, in 1902 that the nations bordering upon the North

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[1] Translated by permission from Revue Scientifique, Paris, May 30, 1914.

Sea (England, Norway, Denmark, Germany, and Holland) established the "Permanent International Council for the Exploration of the Sea," with a central laboratory at Christiania.

Oceanographic studies are of two kinds, one physico-chemical, the other biological. The first includes the determination of the depth of the sea bottom and the study of the bottom; determination of the temperature, the salinity, the gaseous contents of the sea water, the color and transparency of the water, and finally the study of currents. These investigations require the use of special instruments, involving a technique the details of which it is impossible to enter into here. It is enough to say that several of these operations take place at the same time. Thus, when a sounding is made and a specimen of the bottom secured at the point sounded, the temperature is observed and specimens of the water at various depths taken.

The biological investigations pertain to all organisms both animal and vegetable which pass their existence in the seas; to their evolution, to their distribution, etc.: they are specially concerned with the extremely varied organisms which move actively or float passively in the superficial layers, and which constitute the so-called plankton,[1] a name we commonly reserve for the organisms of very small size which often swarm at the surface, in differentiation from the animals of large size like the fishes which inhabit the same regions; to the former class we sometimes give, in contradistinction, the name of microplankton.

The attributes of water with which oceanography is concerned above all are temperature, because of its biological importance; salinity, thanks to which it is possible to determine the geographical origin of the sea waters; and the density, which depends on the two preceding and on the pressure, and which is related directly to the circulation of the water, as much in the vertical sense as in the horizontal. The color and transparency are less important, though not negligible, for they help to better define the biological complex in which the plankton is evolved.

In order to capture the plankton organisms, as well as the animals swimming at different depths, nets much varying in form and dimensions are used, of which some can be closed at any desired depth; for the animals which live permanently on the bottoms, recourse is had to trawls or dragnets of different types. All these oceanographic operations require on board the vessel from which they are performed a special equipment of winches, cables, drums, and booms, for the immersion and recovery of the large nets.

In founding the "Permanent International Council for the Exploration of the Sea," the nations bordering on the North Sea considered that it was to their interest to know the physical condition of that sea and the biology of the fishes which are found there. They have divided up the immense task which is to be carried on jointly according to a program in which each nation has the share most suited to it. The investigations undertaken by all the parties have culminated in an imposing array of publications appearing under the titles: Rapports et Procès verbaux; Publications de circonstance. (Conseil permanent international pour l'exploration de la mer, Copenhague.)

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[1] From πλαγκτός, wandering, vagabond.

III.

From the point of view of purely oceanographic investigations, the Scandinavians, who have so courageously explored the Arctic regions, have shown themselves to be ardent enthusiasts. During the last 15 years the Norwegians have especially distinguished themselves and their investigations have caused such a stir in the scientific world that we must summarize briefly the results.

In 1895, Dr. J. Hjort, the distinguished director of the scientific fisheries service of Norway, in his annual report called attention to the impossibility at that time of determining where the fishes live when they abandon the littoral waters. "No one," he said, "knows what becomes of the cod, the eel, the herring, or the mackerel, when they leave the shore waters. This is a point in urgent need of investigation. No nation is more interested than Norway in deciding the question, for excepting those of the coast of Söndmöre (Aalesund), the fisheries are almost exclusively littoral, and the deep sea remains for the fishers of that country a virgin ground." He emphasized the necessity of having a steamer well equipped to undertake careful investigations, based on the technical oceanographical knowledge so far acquired. The Norwegian Government was so much impressed by Hjort's appeal that in July, 1900, the learned naturalist and his collaborators were ready to make their first cruise on the *Michael Sars*, built in England after the plans of Hjort himself, the arrangement and equipment of which have served as a model for similar vessels. The practical utility of a technical study of the sea was quickly admitted among the Norwegian fishermen. I recall that in 1908, when I was taking the very instructive course of Meeresforschung (studies and investigations relative to the sea) instituted at Bergen, the president of the organization committee, a shipowner, on the day of the inauguration of the lectures, delivered an address which greatly impressed his cosmopolitan audience, and in which in its true light he described the service which oceanography had already rendered to the fisheries.

To the lot of Norway, in the division made by the permanent council, fell the Norwegian Sea with its fjords; that is, the northern part of the North Sea between Norway, Iceland, and Jan Mayen. The plan of work from a hydrographic point of view was largely inspired by the very valuable investigations by the Swedish scholars Otto Pettersson and Gustaf Ekman, in the Skagerack, to solve similar problems. The plan comprises two parts:

1. The determination of the temperature and salinity in order to understand the distribution of the different layers of water and of the currents, both at the surface and in the depths.

2. The recording of the changes which take place at different seasons of the year and during a series of years.

Thanks to the labors of Fr. Nansen, director of the international central laboratory at Christiania, and of B. Helland-Hansen, it can be said that to-day the first part of the plan is nearly completed, and successfully. The temperatures and the salinities have been recorded with all the desired precision in the seas bordering upon Norway, and the same has been done with regard to the principal currents, with the characteristic variations. Concerning these currents, whose study is one of the principal aims of oceanography and presents very great difficulties,[1] we are specially well informed as to their direction, but we have less information as to their speed, although on this aspect we have obtained very interesting data, especially in the deeper parts of the Gulf Stream. The second part of the program is under way but much less advanced, because in winter the waters of the Norwegian Sea are troubled by almost continual storms; frequently there occur, at short intervals, marked changes within restricted areas. Variations in the distribution of different layers of water, in the direction and speed of the currents, can be determined only by constantly collecting records from a great number of adjacent stations.

We now know the origin and the characteristics of the principal layers of water, affording the two learned Norwegian oceanographers the basis for a monograph of the hydrographic conditions of the sea which washes the shores of their country. An approximate estimate has been made of the volume of water and the amount of heat brought by the Gulf Stream into that sea. Now, the amount of heat coming from the warm current has a marked influence on the winter climate of Scandinavia. Records kept continuously during the month of May have shown that the annual variations in the amount of heat from the Gulf Stream correspond to variations in the temperature of the air in that country. Thus, according to the amount of heat brought in by the current, measured and calculated in the month of May, it should be possible to predict whether the following winter will be warmer or colder than usual. The temperature of the littoral waters in May is correlated with the rainfall of the preceding year in the north of Europe. Furthermore, the fluctuations in the fisheries likewise correspond to the annual variations of the waters of the coast. These conclusions, though resulting from five years of intensive study, can not yet be regarded as final. Nevertheless, the correlations thus far determined permit us to hope that hydrographic researches conducted methodically and with perseverance will furnish data useful to meteorology and to agriculture.

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[1] Cf. Ch. Gravier, "Les récentes recherches océanographiques en Norvège," in the Revue gén. des Sciences pures et appliquées, 1909, No. 2, pp. 84–89.

IV.

From the beginning the planktonic investigations have been associated with hydrographic work. We have acquired a general idea of the distribution of the layers of water in the Norwegian Sea and the nature of the principal plankton organisms. The boundaries of certain layers of water and of the distribution of certain planktonic types have shown an interesting correlation. Enormous collections have been made in order to ascertain the changes in the qualitative and quantitative composition of the plankton at different seasons; and the critical and extended study of this material will lead to the preparation of distribution charts, by region and by month, which will serve as a basis for our future knowledge. The explorations in the North Sea proper, where the conditions are less complex, permitted us to affirm that there are in the sea definite areas where certain species spawn, and that the young stages are carried long distances by the play of the currents. It has also been found that the presence of masses of the principal plankton species on which the fishes feed is correlated with determinable, natural conditions.

Wherever possible to do so, we have sought to understand the fauna of the sea bottom, which has for us more than pure zoogeographic interest, for certain kinds of fishes are made up from this fauna. Thus, at the Danish biological station, Dr. C. G. Joh. Petersen has made some very interesting observations on the bottom animals which constitute the food of the plaice, and has drawn from them conclusions useful in the plaice fisheries. The work of Appellöf along the same lines has led to conclusions pertaining to the geographical distribution of certain animals, and also the physical conditions of the earth, as, for example, the very probable subsidence of the Faroe Bank to the south of the islands of that name.

V.

Among the elements of the plankton the attention of Norwegian oceanographers has been especially concentrated on the eggs and larvæ of fishes. Important discoveries have been made from the very first cruise. In the summer of 1900 the *Michael Sars* found young stages (a few centimeters in length) floating hundreds of miles from the banks where it was supposed the fish had spawned. The following year, on the banks to the north of Norway, they gathered recently spawned eggs in great abundance above some shoals of spawning fish. A chart was carefully prepared showing the spawning grounds, and, moreover, one of the commissions (commission A) named by the "Permanent International Council for the Exploration of the Sea" was given the task of preparing for the entire area of the North Sea a chart of the spawning grounds of the fishes of the very important family of Gadidæ (of which the cod (Gadus) is the type). Investigations have shown that each of the 15 species of Gadidæ caught on the coast of Norway chooses its particular spawning ground—sometimes extremely limited—which offers the natural conditions that that species seeks during the spawning period. Depth, temperature, and salinity appear to be predominant factors in this matter. While certain species, such as the hake, cod, and haddock, spawn on the littoral banks and at depths which speaking broadly never exceed 200 meters, most of the other species of this family breed in greater depths in water of oceanic character. The larvæ are carried far from the breeding places by the currents, which play a predominant rôle in the transportation of young fish into different waters. This passive distribution of the pelagic stages has been made the object of joint investigations by the Danish, English, Germans, Dutch, and Norwegians.

The herring, whose life history has been worked out so carefully by Heincke at the Heligoland biological station, has also been closely studied in Norway by several naturalists, who have distinguished on the coasts of their country four different types of herring corresponding to different stages of development. The one which is given the name spring herring is in the state of sexual maturity, its length varying from 24 to 37 centimeters and its age from 3 to 14 years. The same individual may spawn 10 or 14 times. Great differences have been found in the size of herring, according to localities. While the spring herring of Norway reach 37 centimeters at 10 to 14 years, that of the Zuyder Zee does not exceed 26 to 27 centimeters, and that of Breitstadfjord not more than 23 to 24 centimeters. J. Hjort and Einar Lea have shown that, as G. O. Sars had supposed, the migrations of the herring are much more extended than had been previously suspected. All these facts are of the greatest importance from the point of view of the fishing industry.

VI.

In addition to investigations similar to the foregoing relative to the salmon and the sprat, the *Michael Sars* has been utilized also for fishing experiments and for practical investigations directed by its commander, Capt. Thor Iversen. The aim was to get in touch with the fisheries in order to acquire a complete knowledge of the banks and grounds exploited for fishing and to see the fishers at work, together with their appliances and their methods. During these practical researches Capt. Thor Iversen discovered grounds abundantly stocked with fish which the fisheries had until then neglected. At certain places where they sought to get a general idea of the grounds, they found fishes in such quantity that they began at once to exploit industrially these unsuspected riches. When I stopped at Bergen, in 1908, there were in the famous fish markets of that city an immense quantity of halibuts, which came from a very rich bank accidentally discovered by the *Michael Sars* some time before. In these operations the primarily scientific ship was aided by fishing boats hired for the purpose, with competent zoologists aboard. It is due to the earnestness and intelligent energy of Hjort and the collaborators whom he was fortunate enough to gather around him that success many a time crowned their efforts. These oceanographers succeeded in finding new forms of fishes and indicated methods of capturing them, thus aiding in the development of a new industry.

VII.

Desirous of extending their researches into the Atlantic, whose relations with the Norwegian Sea they had studied, the Norwegians in 1910 undertook, thanks to the generous collaboration of Sir John Murray, the well known oceanographer of the *Challenger* expedition, a cruise in the northern part of that ocean, which proved extremely profitable as much from a biological point of view as from a physical. The observations of B. Helland-Hansen in the vicinity of the Azores show that the sun's rays penetrate much deeper than had been believed until then, for at 1,000 meters from the surface photographic plates still received distinct impressions, and certain rays from the most refrangible part of the spectrum penetrate much deeper yet. By an ingenious contrivance which permitted of fishing simultaneously at different depths, naturalists of the *Michael Sars* were first enabled to study the vertical distribution of a certain number of species of fishes and of crustacea, and to clear up a number of biological questions. The general results of this expedition have been presented in a very comprehensive work written by the two chiefs, Sir John Murray and Hjort.[1]

VIII.

In the United States, where Maury, Bache, Pillsbury, and others were among the first to scientifically study the sea, there has been a strong trend toward oceanographic studies. At the tropical biological station at Tortugas, Fla., founded by the Carnegie Institution of Washington, they have begun with the *Anton Dohrn* a series of hydrographic and biological studies covering the Caribbean Sea and the very sources of the Gulf Stream. "It would be a source of regret for Americans," writes Dr. Alfred G. Mayer, director of the Tortugas station,[1] "to fall to an inferior level in this important field of studies."

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[1] Sir John Murray and Johan Hjort, The Depths of the Ocean, with contributions from Prof. A. Appellöf, Prof. H. H. Gran, and Dr. B. Helland-Hansen. Macmillan & Co., London, 1912. 821 pp., 575 figs. in the text, 9 pls., of which 7 are colored.

At the San Diego marine biological station on the coast of California, the *Alexander Agassiz* is methodically carrying on the exploration of the coast of southern California. This ship is provided with all the necessary machinery and apparatus for dredging, sounding, fishing, determination of temperatures, taking specimens of sea water at all depths, measuring currents, and measuring the intensity of the light in the sea water.[2]

In addition to these, the *Grampus*, a schooner specially assigned to this duty through the cooperation of the United States Bureau of Fisheries and the Museum of Comparative Zoology of Cambridge, Mass., has been given the task of investigating the characteristics of the Gulf of Maine, from the point of view of temperature, salinity, the currents, and the plankton. The fact that waters of diametrically opposed origins (the Gulf Stream and the cold littoral current) here meet, leads one to think that a study of this gulf, using modern methods, would be of interest from an oceanographic point of view and might have a favorable influence on the quite considerable fisheries of which it is the headquarters. H. B. Bigelow, who directs the cruises of the *Grampus*, has just published the chief results of the campaign of 1912. He seems to establish the fact that the Gulf of Maine owes its low temperature and its low degree of salinity chiefly to local causes—to its geographical position and its partial isolation by the Georgian Bank. The cold water comes from the St. Lawrence and its tributaries and probably has no connection with the cold Labrador current, contrary to the opinion generally held in scientific works as well as in popular belief. Bigelow and his collaborators propose to study the correlation between the geographic and seasonal distribution of the most important elements of the plankton and the physical characters of the waters in which they live, and to try to determine the factors controlling their periods of reproduction, their migrations, etc. The work of 1912 was but a preliminary investigation of the problem; the materials gathered require long study before yielding the results which we may expect from them.

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[1] Annual report of the director, 1912, p. 188.

[2] Cf. Ch. Gravier, le Laboratoire de Biologie tropicale de Tortugas (Floride), Revue génér. des Sc. pures et appl., 1913, No. 23, pp. 874-882. La station biologique marine de San Diego (Californie), ibid., 1912, No. 11, pp. 440-443.

The operations of the *Grampus* will be continued from year to year. They were taken up in November, 1912, by the steamer *Blue Wing*, an auxiliary to the *Grampus*, during the operations of fish culture in the winter season. In 1913, in again taking the measurements at the stations of 1912, to determine the changes from year to year, Bigelow traversed the cold waters between the coast and the Gulf Stream from Cape Cod to the entrance to Chesapeake Bay. In pursuing their investigations relative to edible fishes the American naturalists discovered very extensive beds of scallops (*Pecten magellanicus*) along the whole length of the States of New York, New Jersey, and Maryland, which promise to be a source of very important new fisheries.

IX.

Until these later years, aside from the cruises of the Prince of Monaco and the local investigations such as those of Pruvot at Banyuls and of J. Richard in the Bay of Monaco, almost everything from an oceanographic standpoint remained to be done in the Mediterranean. But since 1910 the situation has changed entirely. The Italians have taken up the work with a remarkable zeal, greatly excited by the acquisition of Lybia (Tripoli). The law of July 13, 1910, modified by that of June 5, 1913, established the "Reale Comitato talassografico italiano." Paragraph 1 of article 1 of that law thus defines the duties of that committee: "There is established from the 1st of July, 1910, the Royal Italian Thalassographic Committee, having executive functions to carry on the physico-chemical and biological studies of the Italian seas, their special relation to the industries of navigation and of fishing, and the exploration of the higher atmosphere in its relation to aerial navigation. The committee received (1) a contribution from the Government of 60,000 francs a year: (2) fixed or temporary contributions from other public departments, and from private and scientific bodies. It met at Naples in 1910, at Rome in 1911, at Genoa in 1912, at Sienna in 1914, always on the occasion of the Congress of the Italian Association for the Advancement of Science, whose president is at the head of the Thalassographic committee.

Furthermore, the committee felt the necessity of having a central institute of marine biology which would permit making, besides independent biological studies, an examination of the material collected during the cruises and the distribution of sorted lots to competent specialists, to whom recourse must inevitably be had. The place chosen is Messina, whose rich plankton has attracted so many naturalists. A first contribution of 100,000 francs has been furnished by the Government; the work of construction was begun at the end of last January. From the financial appropriation for 1912 to 1913 the sum of 20,000 francs (incorporated in the extra budget for the Navy) for each appropriation is set aside for the construction and furnishing of this institute. Besides the Royal Italian Thalassographic Committee, they have created local committees to participate in the general work, but especially to study local problems: Ligurian, Adriatic, Parthenopian, and Sicilian committees.

It is to the study of the Adriatic that the Italian efforts are mainly directed. An agreement concluded with the Austro-Hungarian Government following a conference of delegates of the two allied countries at Venice, in May, 1910, paved the way for this collaboration. Four cruises each year, in February, in May, in August, in November (those of November, 1911, February and May, 1912, could not be carried on on account of the Tripolitan war), were to be undertaken following eight determined traverses, making observations and measurements according to an established technique with the standard instruments. The fourteenth cruise of the *Cyclops* (Italy) and of the *Naiad* (Austria-Hungary), which were to close the program of periodical investigations to be made in the Adriatic, took place in February, 1914.

Finally, the international commission for the study of the Mediterranean has thus far met three times under the honorary presidency of S. A. S. the Prince of Monaco. At the last meeting, at Rome, in 1914, the Italians presented a complete plan of investigations for that sea, inspired by that which they had followed in the Adriatic, and laid out work for each of the nations bordering on the Mediterranean.

THE KLONDIKE AND YUKON GOLDFIELD IN 1913.[1]

By H. M. Cadell, B. Sc., F. R. S. E.

[With 6 plates.]

Klondike was once a name in every mouth, and in the last years of the nineteenth century it nearly became incorporated in the language as a new synonym for all that is rich and prosperous. But of late it has been little heard of on this side of the water, and its early bloom has faded away. The sensational pockets of fine placer gold, that attracted hordes of hardy adventurers from every quarter, have now been mostly depleted and new ones have not been discovered to maintain the early reputation of the field. But while this part of the Yukon district can not any longer be called a poor man's goldfield, it still contains a considerable quantity of alluvial gold that can be profitably won by the application of capital and brains. In any case, it is a district well worth a visit, and apart altogether from gold it has other possibilities in the way of future development. Besides this, it is full of points of great geographic and scientific interest, and in this remote and imperfectly explored northwestern corner of the British Empire the geologist and the geographer will find many new problems awaiting them which it will be a delight to discuss and investigate for many years to come.

I had the advantage in September, 1913, of paying a short visit to the Yukon district with a few members of the International Geological Congress, under the able guidance of Mr. R. G. McConnell, of the Canadian Geological Survey, and other specialists and officials who had already explored the goldfield on behalf of the Government, and had published from time to time accounts of its industrial and geological development. We were thus placed in the favorable position of being able to see in a short time many things that might never have come under the notice of a solitary and unguided stranger, and with the literature and maps that were liberally provided it was possible to form a good general idea of the district, that might be made serviceable to our respective countrymen in distant lands, whether they might be men of science or people with more material interests.

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[1] Reprinted by permission from the Scottish Geographical Magazine, July, 1914.

The Yukon territory is most easily reached by steamer from Vancouver through the lovely forest-clad islands and straits on the coast of British Columbia and the United States coastal belt of southern Alaska. In the last part of this most interesting voyage of nearly 1,000 miles the route lies along the Lynn Canal, a narrow arm of the sea that reminds a Scot of Loch Linnhe, but is bordered by higher mountains with snowy crests, and glaciers creeping down the glens to near sea level. The Lynn Canal is a straight fiord about 85 miles long, but it is only the prolongation northward into the mountains of the Chatham Strait, a deep submerged valley among large islands, whose whole length is 250 miles. The width varies from 3 to 6 miles, and the depth from 1,000 to 2,500 feet. Although this narrow inlet penetrates so far up into the mainland, its head, with that of all the other fiords on the coast north of the Portland Canal, now belongs to the United States. The latter claimed it, and Lord Alverstone as chairman decided in their favor and against Canada in the boundary dispute whose settlement caused so much bitterness in the Dominion in 1903. The head of the Lynn Canal lies at Skagway, the gateway to the Yukon, a wretched little town with decayed wooden houses and grass-grown streets, the scene of many robberies, riots, and murders at the time of the gold rush, which the police authorities outside of British territory had neither the power nor the energy to control. Skagway is not and can never be of much use to the United States, except as an obstruction to Canadian progress, but it might be of some advantage to the vast Canadian hinterland less than 20 miles inland. If, at some future time, the United States Government ever wished a cheap opportunity to show a little practical good will to their progressive northern neighbor, they might advantageously dispose of the head of the Lynn Canal, and thus give Canada one much needed outlet along a strip of some 500 miles of seacoast from which the Dominion has been cut off by the award of the lord chief justice.

Skagway is surrounded on three sides by a plateau of steep and rugged mountains through which to the north there are two trails, by the White Horse and the Chilcoot passes, respectively. Up these wild and difficult ravines thousands of hardy adventurers trekked and struggled with their heavy packs, tools, and tents, in the mad rush to the expected El Dorado, 500 miles away. Soon after the gold was found in sufficient quantities, a 3-foot-gauge mountain railway was laid up the White Pass (fig. 1). It runs from Skagway to the summit at 2,887 feet above sea level and on to Lake Bennett, a distance of about 40 miles. It traverses a wild, ice-worn, granitic plateau, strewn with moraines and sprinkled over with lakes at the foot of bare snowy peaks, 5,000 to 6,000 feet in height, reminding one of parts of the west coast of Sutherland or of the interior of Norway.

Lake Bennett, a narrow and picturesque sheet of water between high mountains, is 27 miles long and its outlet at the northern end is one of the tributaries of the Great Yukon River. The sixtieth parallel, that of the south end of the Shetland Islands, crosses the lake some miles from the deserted town of Bennett at its head. At the time of the gold rush there were 5,000 people at Bennett in houses, huts, and tents, and the fact that a wooden Presbyterian church was built there shows that more than 10 righteous men were to be found among that surging and sordid crowd. The church is now almost the only building besides the railway station that is standing, but it is boarded up and falling into decay. The photograph I had time to make during our short halt for lunch shows this little ecclesiastical pile with its spire pointing to the sky adding a human touch to the grand but desolate picture (pl. 1).

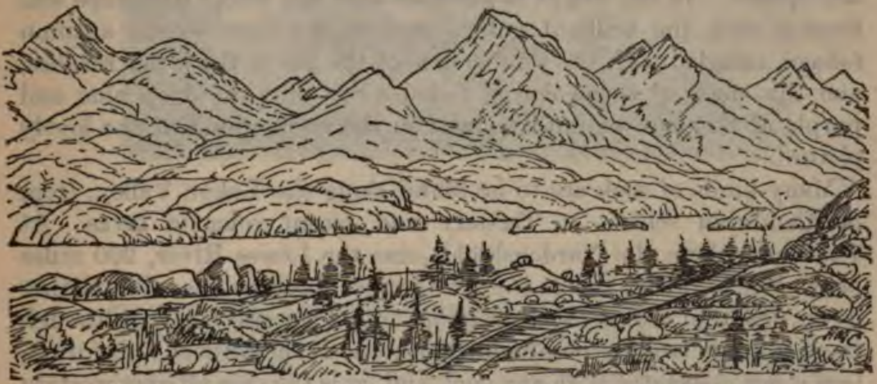


FIG. 1.—Scenery at summit of White Pass, on Yukon Railway. Altitude, 2,800 feet.

The original diggers here got into boats and canoes, and navigated their frail craft through the lakes and rapids on the remaining 531 miles of their adventurous journey to Dawson City. The whole distance from Skagway to Dawson is 571 miles, and the first part of the journey is covered by 110 miles of railway. The line runs at the foot of the steep granite mountains along the shore of Lake Bennett to White Horse, a few miles above the tame but beautiful Lake Laberge, where safe navigation begins. At the north end of Lake Bennett the country becomes less rugged, and the mountains lower and more rounded, and there are broad valleys covered with glacial drift and herbage. Lake Laberge is a little over 2,000 feet above sea level and the whole fall to Dawson is about 1,000 feet, which gives an average gradient in 435 miles of a little more than 2.5 feet per mile. There are no serious declivities below White Horse, and only at one place—the Five Finger Rapids below the Tantalus coal mine—is there much risk to travelers during the season when the river is open to navigation by flat-bottomed, stern-wheel steamers.

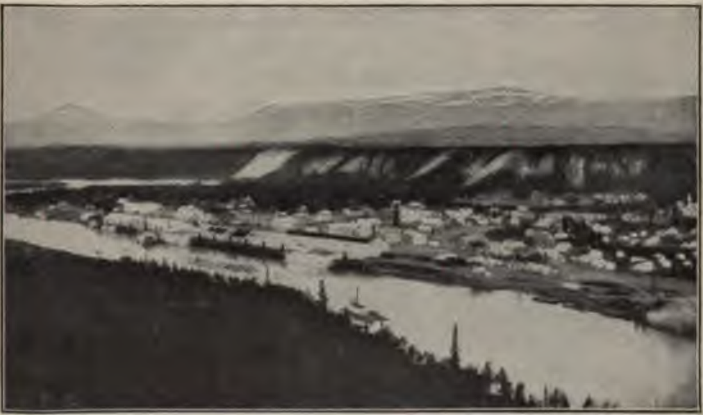
The Lewes River, flowing from Lake Laberge, and the Yukon, which it is a large tributary, flows northward in a channel with man windings between high terraces of gravel and sand. White Horse situated on the flat river bank at the base of one of these high grav terraces, well exhibited in plate 1. The upper part of the valley full of glacial detritus and fine mud from the glaciers that once co ered the higher country, and the river is busy excavating a low channel in these loose deposits. Over a large district the sandy so under the grass has a skin of impalpable white ash from 6 inches to couple of feet deep, that has been wafted hither at the time of som prodigious eruption of an unknown volcano long ago, and has falle quietly like a shower of fine snow over the face of hill and dale.

Though the latitude is that of our Shetland Islands, this part of th Yukon Valley is thickly covered with trees, mainly aspen, birch, alde and spruce. In the bright September days the whole landscape wa blazing with the brilliant golden and scarlet tints of the autum foliage, mingled with the somber hue of the firs in the lower reache and this mass of rich coloring faded away into the deep blue an purple of the bare mountain crests in the background of the lovel picture.

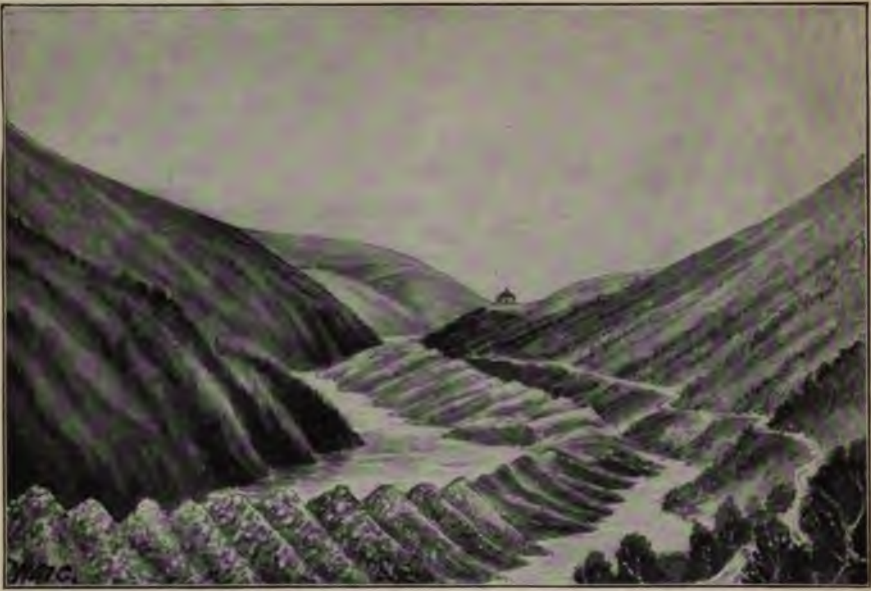
Many kinds of rock are to be found along the Yukon Valley, fro pre-Cambrian schists to Tertiary and recent volcanic lavas. A Tantalus, where the Nordenskiöld joins the Lewes River, 200 mile below White Horse, and at the Five Finger Rapids some miles farthe down, seams of coal are seen cropping out on the cliff faces. Althoug there is much true Carboniferous limestone in the district, this forma tion is not associated with any coal, and, as is the case all over wester Canada and Alberta, the coal is all of younger age, and is interbedde with Jurassic and Cretaceous strata. The seams are sometimes ove 7 feet thick, and at Tantalus there is a mine in operation in the cli at the river's edge where several thousand tons have been worke The coal is of great use, as the woods near the river have been largel cut for fuel and for mining and building purposes, and the supply thus becoming scarcer every year. But the quality of the coal is no very good, and its percentage of ash is high.

Near White Horse a valuable body of copper ore is also being mine in the hills, and if enough good coal were to be discovered a grea impetus would be given to permanent local industry of a better kin than precarious gold mining. The region has for half the year at leas a good and sunny climate, and as it is now fairly accessible it ma some day develop into a useful grazing or agricultural territory. I is, of course, still largely unexplored, and more valuable minerals an other resources may yet be discovered in the unfrequented remot hinterland out of sight of the river highway.

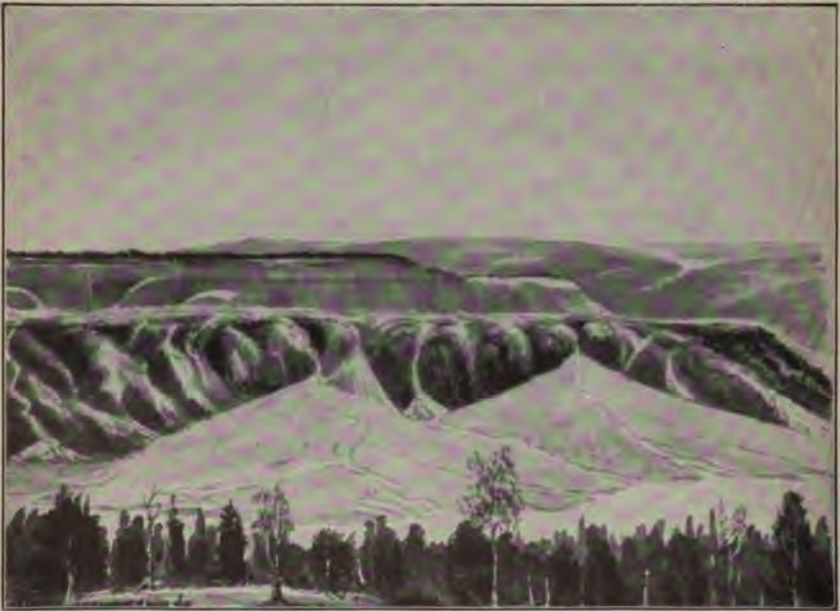
LAKE BENNETT.



THE LEWES VALLEY AT WHITE HORSE, SHOWING HIGH TERRACE OF GLACIAL GRAVEL.



A "HUMAN MORAINE." EFFECT OF GOLD DREDGING ON TOPOGRAPHY OF HUNKER CREEK, KLONDIKE.



EFFECT OF HYDRAULIC SLUICING OF UPPER WHITE GRAVELS, BONANZA CREEK, KLONDIKE.

A curious and interesting feature of the district must now be mentioned. The numerous lakes, the deeply eroded ice-worn valleys, and the widespread deposits of gravel and morainic material in the upper part of the Yukon Basin, all tell of the former wide extension of the glaciers, whose diminished representatives have long ago shrunk back into the remote glens and corries among the higher mountains. But as we sail northward toward the Arctic Circle these traces of former extensions of land ice diminish, and finally disappear altogether. The moraines are no longer to be seen, and all we find in the valley is a wide deposit of very fine sand or silt, such as is washed in a milky flood from beneath any valley glacier. These glacial silt beds finally dwindle away, and the solid rock surface becomes soft and rotten, and covered with screes and loose débris produced entirely by its own disintegration.

Long before we reach Dawson all traces of glaciation have disappeared, and the noble river winds back and forward between the steep sides of a valley, a quarter of a mile wide, cut out of the old and decomposed plateau of crystalline rocks. The latitude of Dawson City is that of the south of Iceland, and its level is a little more than 1,000 feet above the sea. The whole of the old alluvium in the valley bottoms is frozen hard to a depth of over 100 feet, and the summer sun is only able to thaw a few feet of the surface before the winter's cold sets in, and the whole region is incased in snow and ice.

Now, it is a matter of common knowledge that the cold was at one time so intense in the Northern Hemisphere that the northern parts of Europe and Canada were covered for a time by huge glaciers, or ice caps, such as now envelop the whole of Greenland. The whole of the Pacific coast of British Columbia and the southern end of Vancouver Island is intensely ice worn. In the eastern part of Canada the polar ice cap in the glacial period covered the country as far south as the Great Lakes, and left the Province of Ontario sprinkled over with clay and stones from far-off northern sources. Wherever the great ice sheet went it swept away all the loose rock, river alluvium, and soil that lay on the preglacial land. The underlying rocks were scoured and polished, and when the ice melted at last, the valleys and plains were left buried under a covering, not of soil or river alluvium in stratified beds, but mainly of unstratified bowlder clay or till, produced by the grinding of the creeping ice, which was at places thousands of feet in depth.

These considerations may seem remote from the subject of the Klondike gold deposits, but in reality the opposite is the case. The original valley gravels, the accumulations of long ages in which small quantities of gold derived from the adjacent rocks had become collected, sorted out, and concentrated by the long-continued action of the ancient rivers—these auriferous deposits were not swept away here as they were at other places during the glacial age, and they were only partially washed out by the rivers of later times. They were left, or at least partially left, lying undisturbed in certain sheltered valleys until their value was discovered by a few prospectors. The final process of removal, or at least disturbance, of the old gravels was not long delayed after this important discovery had been made.

The reason why this northern territory thus escaped the besom of destruction that swept other regions bare was doubtless the fact that the climate was so dry that there was little or no rain or snow to produce a great glacier. However great the cold may be at any place, it is obvious there can be no frozen water if the water is not first there to freeze. Had there either been no ice age, or else a dry climate during that epoch, placer deposits of gold might also be found in eastern Canada, Scotland, or Scandinavia, where small quantities of the precious metal occur in the local crystalline rocks, and the almost complete absence of alluvial gold is one result of that prolonged icy invasion of these countries. The deeply frozen subsoil in the Klondike district is all that remains to tell us of the great cold of the glacial age, for there is no doubt that the ground has remained in a frozen state since that period, and that its covering of moist peat has effectually prevented it from becoming thawed by the warm sun in summer.

The Yukon goldfield, so far as it has been explored, is apparently mainly confined to the vicinity of Dawson City, although small quantities of gold can be found in the sand of the Yukon for hundreds of miles up the valley. Indeed, our party panned a little gravel and got specks or colors of gold where the steamer stopped for fuel, 10 miles below Big Salmon River, a tributary of the Lewes River above Tantalus, near the place where gold was first discovered in 1881. We passed an old digger who, we were told, can wash out about £2 worth of gold a day during good weather, when the water is low and the banks well exposed, in certain parts of the channel.

Dawson City (see map, fig. 2) is situated on the alluvial flat close to the mouth of the Klondike, a small river which rises in the Ogilvie Range and flows southward and westward into the Yukon. The Bonanza Creek is a little stream in a deep and wide gully that enters the left bank of the Klondike Valley just above the confluence at Dawson, which is celebrated for the richness of its auriferous gravels. The Klondike is joined by two other tributaries on its left bank farther up, Bear Creek and Hunker Creek, the latter of which is by far the larger and more important. These and other streams all occupy smooth-sided valleys traversing an old peneplain or dissected upland composed of rounded hills and ridges. These smooth ridges originate in and branch outward from the Dome, a round-topped eminence reaching to an elevation of 4,250 feet, the highest mountain and topographic center of the whole district. It is 19 miles southwest of Dawson and commands a magnificent view of the surrounding tract of brown, grassy uplands, sweeping away northward for 40 miles to the snowy peaks of the Ogilvie Range. I had time to make a topographic sketch of the panorama from the summit, which was nearly clear of snow, and have now reproduced part of it to convey to the reader an impression of the general appearance of that remote and lonely region, the haunt of the caribou and the ptarmigan. (See pl. 3.)

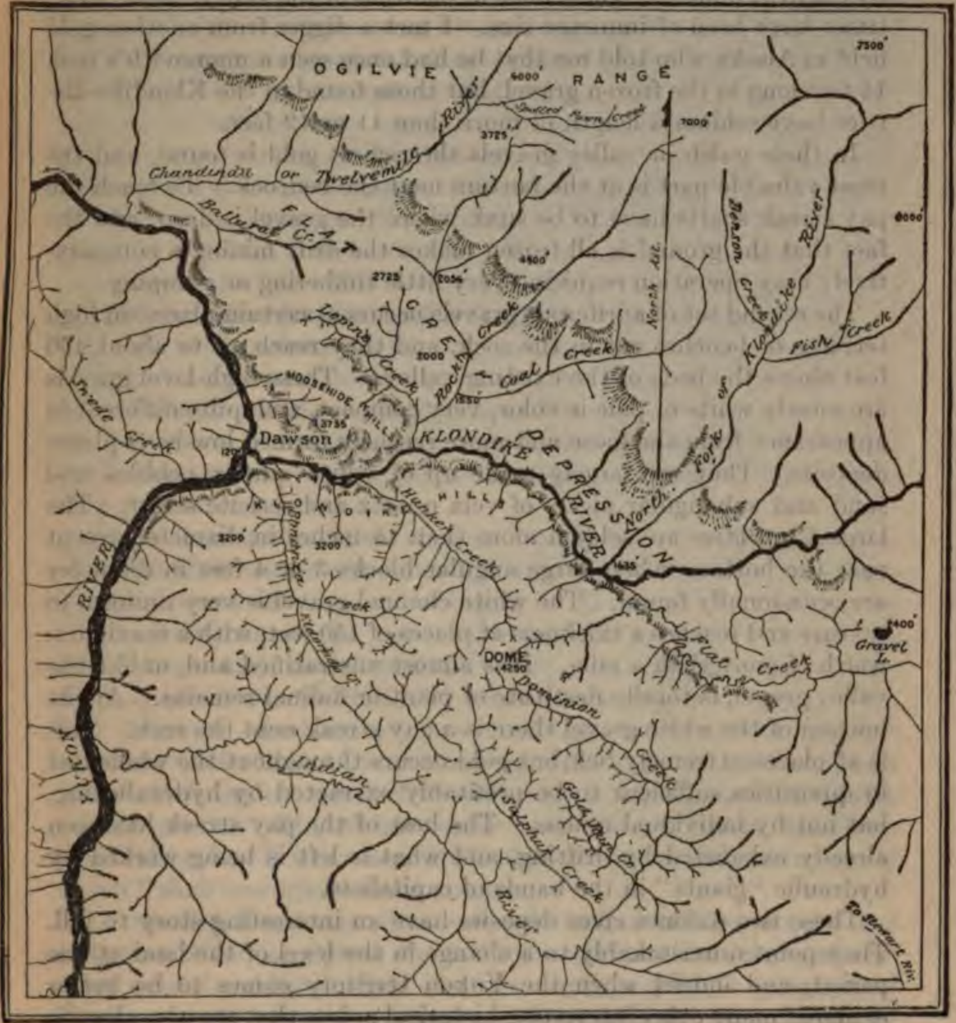


FIG. 2.—Map of Klondike district and vicinity. (From the Geological Survey of Canada.)

The Klondike goldfield has two perfectly distinct sets of placer deposits. In the alluvial flats of the Klondike and its tributaries, the

Hunker and Bonanza Creeks, there is a series of deep gravels covered with soil and peat moss and containing the remains of extinct and existing animals in large quantities. Bones of mastodon and huge mammoth tusks, skulls of buffaloes and bones of bear, musk ox, and mountain sheep, as well as ancient beaver dams, are often discovered by the drift miners. These ancient denizens of the valleys must sometimes have been of immense size. I met a digger from another gold field in Alaska who told me that he had once seen a mammoth's tusk 14 feet long in the frozen gravel, but those found in the Klondike district have seldom a length of more than 11 or 12 feet.

In these gulch or valley gravels the richest gold is found, and the most valuable part is at the bottom next the bedrock. To reach the pay streak shafts have to be sunk where the gravel is deep, and the fact that the ground is all frozen makes the drift mining a comparatively easy operation requiring very little timbering or pumping.

The second set of auriferous gravels occurs at certain places on high terraces or benches cut in the rock, and they reach up to about 450 feet above the beds of the existing valleys. These high-level gravels are mostly white or pale in color, very compact, and quite different in appearance from the loose and more recently formed low-level placer deposits. They are largely made up of white quartz pebbles and sand and subangular pieces of vein quartz and sericite schist. The largest bowlders are seldom more than 18 inches in diameter except near the bottom, where large angular blocks 3 or 4 feet in diameter are occasionally found. The white channel gravel is very uniform in texture and reaches a thickness at places of 150 feet, with a maximum width of more than a mile. It is almost unstratified and, unlike the valley gravel, is totally destitute of plant or animal remains. At the bottom of the white gravel there is a pay streak next the rock. This is at places extremely rich, but gold occurs throughout the whole bed in quantities sufficient to be profitably extracted by hydraulicking, but not by individual miners. The best of the pay streak has been already exhausted by drifting, and what is left is being worked by hydraulic "giants" in the hands of capitalists.

These two distinct river deposits have an interesting story to tell. They point unmistakably to a change in the level of the land at one period, and indeed when the Yukon territory comes to be better explored many other interesting historical points that are now obscure will be cleared up. There is evidence of a considerable change in several parts of the Yukon River system since the Tertiary period, and some of the rivers have been able to capture parts of others and so modify the original pattern of the continental drainage. The land has not remained quite stationary, and indeed in Yakutat Bay, in Alaska, as recently as 1899, there was a terrific earthquake, accompanied by a local movement of the land and an upheaval of the coast line to the extent of 47 feet in one place.

In the Klondike and Dawson instance the movement was one of upheaval of the whole region to a height of at least 700 feet. There were ancient river valleys with sluggish streams, where the white terrace gravels slowly accumulated and in whose bottoms the grains of gold derived from the waste of the small quartz veins in the neighboring hills became concentrated in streaks and pockets. When the uplift began the rivers acquired fresh velocity and started at once to deepen their old courses energetically and to cut out new and narrower valleys in their old flood plains. They swept away a great deal of the white gravel, but some of it was left undisturbed, with the gold-bearing streak beneath. The process went on till the rivers had not only cut out deep trenches in the white gravels, but had penetrated far below them into the underlying rock. The gold in the white gravels, perhaps with other gold derived directly from the neighboring schistose rock, sank to the bottom of the later alluvium and was concentrated again in a newer pay streak, while the lighter débris was mostly transported to the distant sea. The climate was mild enough for vegetation to flourish, on which many large animals browsed in peace and comfort, or were preyed upon by more predaceous denizens of the northern wilds.

To come down to more modern times, adventurous prospectors threaded their weary way over this little-explored region, and these hardy pioneers of empire first began to find traces of gold in the Yukon Valley about the year 1869. In 1881 gold was found in the gravel banks and bars of the Big Salmon, and other discoveries were made in the Lewes, Pelly, and Stewart Rivers soon afterwards. The first discovery of coarse gold was made on the Fortymile, another tributary of the Yukon below Dawson, in 1886, and with this evidence of the auriferous character of the district prospecting received further encouragement. In 1894 fresh discoveries drew the miners into Klondike Valley, but it was not till 1896 that the great find was made, of which I shall now give a short account.

In 1894 Bob Henderson discovered gold in Quartz Creek, a tributary of Indian River, at a place about 6 miles south of the Dome, and he went over the ridge to Gold Bottom, another gully, a tributary of Hunker Creek, where he discovered more gold in 1896. He told George Cormack, another prospector in the district, of his luck, and Cormack paid him a visit, but on the way back Cormack, or one of his companions, while stopping for dinner, accidentally turned up some remarkably rich dirt at Bonanza Creek, and immediately pegged out a claim without ever telling Henderson of his own far greater luck.

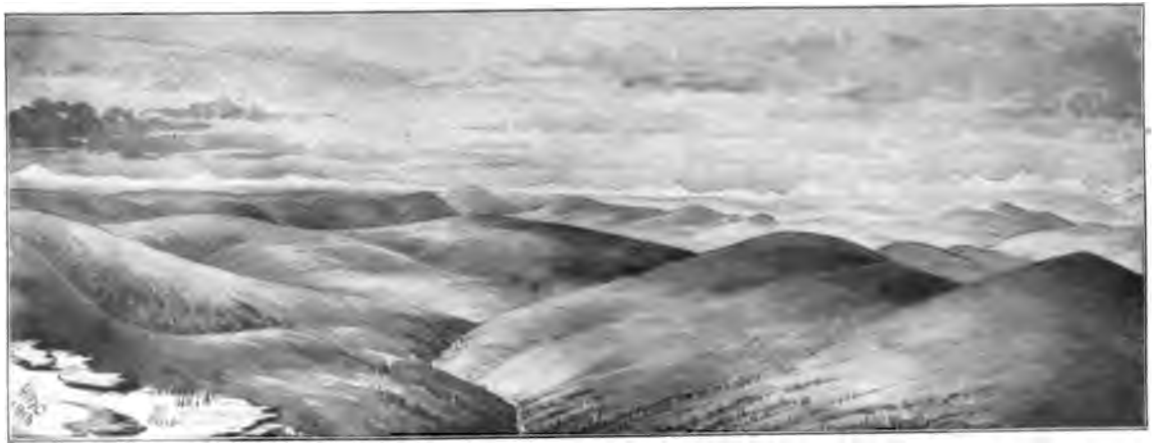
Prodigious quantities of gold were soon found at this spot, and prospectors flocked in from all quarters. Many of them made fortunes in a short time, but not being educated to use wealth properly, it was mostly misused and spent in debauchery. The greatest quantity produced in the district was in 1900, when the output reached nearly four and a half million pounds sterling. One man, Dick Lowe by name, is said to have got out of a fractional claim, 86 feet by 300 feet in area, £120,000, but I was told he spent it in a few years and died in poverty. Others got and wasted as much or more. Cormack was said to be working as a coal miner and Henderson was in 1913 a Government pensioner. One of the quickest fortunes was made by two men who in 27 hours cleaned up gold to the value of £13,000. Many stories are told of the proceedings at Klondike in these "golden days" which are not for edification, and the moral is that wealth too easily and quickly acquired is apt to be the opposite of a blessing to mankind.

At the height of the boom in the winter of 1899 the population of Dawson City is said to have reached 25,000, and that of the whole district 50,000. All these people did not make fortunes, while many lost their lives in the attempt, and soon the richest of the placers became exhausted and the exodus began. At the time of my visit Dawson City had a population of only 2,000, and the place was in a sorry condition, while the surrounding district was almost depleted of drift miners.

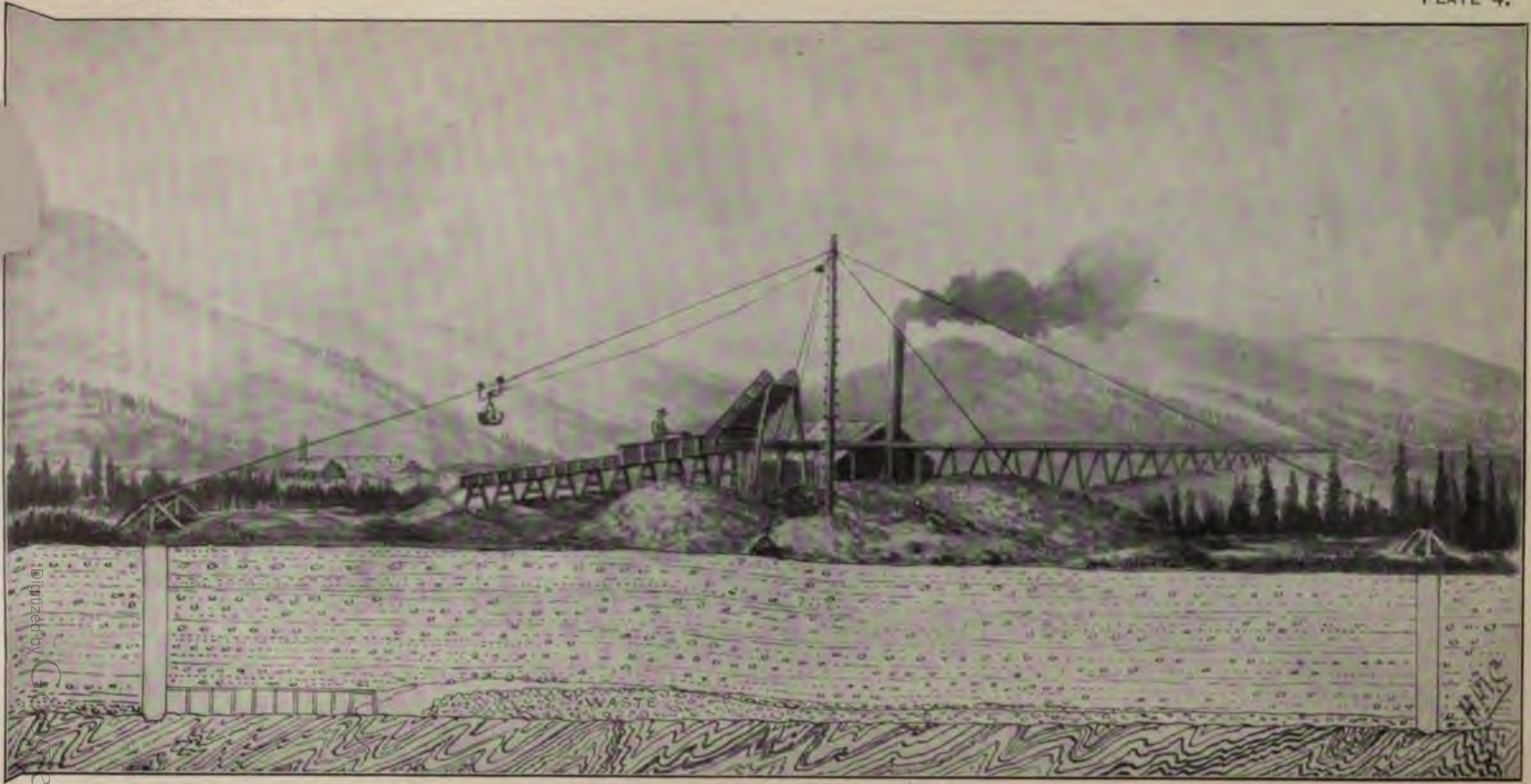
When good gold was found the Government, out of the revenue from the duty that was paid, set to work with exemplary speed to construct roads up the main creeks and over the hills, which greatly facilitated and cheapened transport. We went up Klondike Valley and Hunker Creek by one of these roads, spent the night in the little rest house near the summit in the snow that had begun to fall, and next day returned by Eldorado and Bonanza Creek. My little party of three was fortunate enough in being conveyed round this 60-mile run by Mr. J. W. Boyle in his motor car, not without considerable difficulty and risk at perilous places. Mr. Boyle is the able head of the Boyle Concessions (Ltd.), one of the two large and prosperous companies now engaged in extracting the remaining gold left by the drift miners. Besides showing us great hospitality, Mr. J. W. Boyle, in common with many other kind hosts in Dawson City, gave the visitors much valuable information about the present condition of the gold industry and the methods that are taken to succeed in accomplishing by modern science and capital what in the hands of poor and uneducated men would be a perfectly hopeless task.

The gold in the Yukon field is, as has been said, derived originally from many small veins widely disseminated in the metamorphic schists of the surrounding locality. Large and productive veins have not been found but attempts have been made to work small

PLATE 3.



VIEW NORTHWARD FROM THE DOME TOWARD THE SNOWCLAD OGILVIE RANGE.



SKETCH AND SECTION OF WORKINGS IN FROZEN GRAVELS IN THE LAST OF THE KLONDIKE DRIFT MINES.

ones, hitherto, however, with indifferent success. The long-continued operations of nature before the advent of man have been needed to concentrate these scattered grains into sufficient quantities to be profitable for his use.

The various methods of gold recovery in the Klondike district may be generally classified under three main heads into the following seven subdivisions:

- A. By individual men:
  - (1) Washing surface gravels with shovel and pan.
  - (2) Sluicing gravel with flumes and sluice boxes.
- B. Small parties:
  - (3) Working drift with mechanical scraper and sluices.
  - (4) Drift mining in shafts and sluicing.
- C. Capitalists:
  - (5) Dredging with powerful mechanical plant.
  - (6) Hydraulic sluicing with monitors.
  - (7) Mining and stamping ore in mills.

The first class (A) includes the so-called "poor men's diggings," as all the plant that is required are a few tools and wood to make cradles or sluice boxes and flumes to convey the water required to wash the gravel. The second class (B) requires more financial resources and also more mechanical ability, but a man who has begun from zero may, if successful, quite well gain enough money and experience to enter class B and employ other men or work in company with a party on the cooperative system. Both A and B, however, require fairly rich ground to work upon. But between B and C there is a wide gap, and only men such as Mr. J. W. Boyle, with exceptional ability and command of ample capital, can hope to pass from B to C and work the low-grade placer gravels or quartz veins successfully. The poor men without education who suddenly realized fortunes, but had not the brains to use their money rightly, were not qualified to pass into the last class even though they had the capital to begin with. The survivors, the men with both the mental and material resources, are now left almost alone on the field, and it is to them that the future of Klondike belongs.

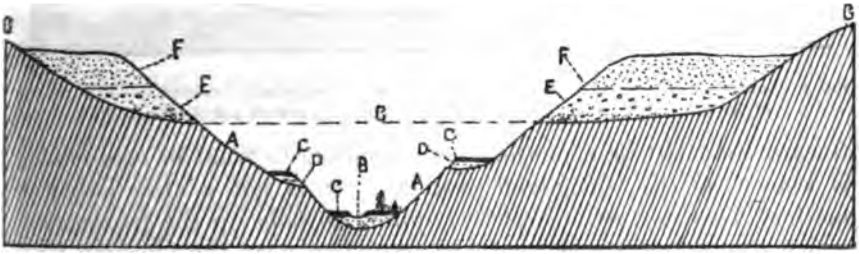


FIG. 2.—Generalized section showing distribution of auriferous gravels at Klondike. *A*, Klondike schists; *B*, stream gravels; *C*, peat or "muck"; *D*, terrace gravels; *E*, white channel gravels of old valley; *F*, high-level gravels; *G*, *G*, *G*, profile of old valley bed.

On our way up Klondike Valley, between Bear Creek and the mouth of Hunker Creek, we stopped to visit the last of the old drift mines in the Klondike Valley, where a party of 21 men were working on tribute in the frozen gravel, which is here 40 feet deep, for which they paid a royalty of 20 per cent of the gold recovered to the owner of the claim. The accompanying diagram, showing a section of the working drawn to scale, and a sketch of the surface arrangements (pl. 4), will convey an idea of the method adopted in this field by miners with a limited amount of capital at their disposal.

A shaft is sunk to the rock surface where the pay streak occurs, and from this a tunnel or heading is driven 50 yards in one direction to the boundary of the claim or the limit of the little field that can be worked easily from one shaft. When this distance is reached a drift is made in the gravel at right angles to the main tunnel on each side along the boundary, so that the working plan is like the letter T to begin with. Then the whole area is gradually worked back toward the shaft on a method corresponding to what in coal-mining is known as the "long-wall system." It is not a true long-wall method, however, as no wall is required to hold up the frozen roof, which is very strong and needs no support near the working face. In mining a coal seam the thin "holing" picked or cut out under the coal is the least valuable part, and the thick stratum above it is what the miners are after. But in the case under notice the opposite principle holds. The thin stratum next the bedrock is the only valuable part. It is, however, too hard frozen to be immediately removed. To undercut the hard mass, lines of horizontal holes are bored close to the bedrock into which pipes with sharp points are driven 4 or 5 feet, and connected with a pipe from a boiler at the pit mouth. Steam is thus injected by means of these steam points, as they are called, for from 6 to 12 hours, and the holing is thawed till it is quite soft and can be easily excavated with picks and shovels. Each steam point requires steam equal to about one horsepower, and thaws from 1 to 3 cubic yards per shift. This thawed gravel is wheeled away in barrows and emptied into a bucket or skip at the pit bottom. The bucket is hoisted to the surface by a steam winch, and by an ingenious arrangement travels along an aerial ropeway and is tipped automatically into the sluicebox. All the surface labor required is that of a man in the sluicebox to throw

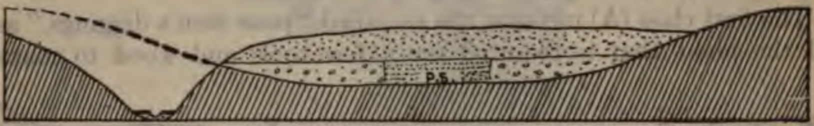


Fig. 4.—Section across Bonanza Valley at Lovett Hill (vertical scale double horizontal). *P. S.*, position of pay streak of coarse gold at bottom of white channel gravels in bed of old valley.

out the stones and another to attend to the engine. In order to give headroom for working, the gravel thus undermined is broken down in lumps and thrown back into the waste, and the loose stuff fills it nearly to the roof. In course of time the superincumbent stratum thaws and subsides gently like the roof of a long-wall working, and closes up the space above the waste, and the surface of the ground sinks down to the same extent

This frozen gravel or "muck" provides a surprisingly strong roof to the working. It is, however, sometimes forgotten that water is a true mineral, and in its crystalline or frozen state is as much a rock as granite. When thus solidified in the interstices between hard grains and pebbles it forms a very strong and homogeneous block without fissures or joints to weaken it or interrupt its continuity. Thus it is that drift miners can work with comparative safety, especially in winter, and only require to leave an occasional solid pillar or put in a little timbering to support parts of the roof that may be weak. In winter time the frost is most intense and the roof not so liable to fall in. In one case on Dominion Creek, a "muck" roof of this kind, unsupported by pillars, is stated to have covered a vault 140 feet wide by 230 feet long, and remained unbroken till midsummer.

The thawing of the gravel was originally carried on by wood fires placed against the face like the ancient method of fire setting to disintegrate the lode in metal mines before the days of explosives, but the use of steam points soon superseded this primitive process. There is, of course, considerable danger of individual stones or slices of the roof dropping down, and fatal accidents have often occurred from this cause. In the mine I have described I noticed a continuous slight shower of sand grains dropping on my head from the thawing skin of the roof, but happily no large hailstones were among them.

The depth of the frozen ground is variable, and is less on the ridges than in the valleys. A shaft sunk on the ridge south of Eldorado Creek reached unfrozen ground at a depth of 60 feet, while one in the valley of the same creek was stopped by running water at a depth of a little over 200 feet. The advantage of the ice is thus obvious from the point of view of pumping, which, if it became necessary, would put an end to many of the poorer drift mines in the valleys. But for surface work the ground must be thawed artificially when the gravel comes to be handled on a large scale at a depth not affected by the summer sun.

The bed of peat, or "muck," as it is called, that covers the valley bottoms acts as a nonconducting skin and prevents the sun's rays from penetrating the frozen mass, but when it is cleared off the surface thaws permanently to a depth of several feet, and can be removed by a scraper and sluiced or otherwise treated.

We now come to the more important methods of gold recovery by which the output of the field is being maintained after the drift miners have extracted all that is possible by their simple and inexpensive appliances. There are, as we have seen, two kinds of gravel, one in the valleys and the other on the high terraces, and to extract the remainder of the gold two separate methods must be thus employed.

The valley gravels are worked down to a certain depth by very strong and specially constructed dredgers, with internal revolving trommels or screens, and extensive sluice boxes with the usual riffles to catch nuggets and gold grains. The terrace gravels are removed by hydraulic giants, and washed through flumes and sluice boxes into the already depleted valley bottoms, and when all these complicated operations are completed the physical character of the gullies is completely changed.

The dredging operations are mainly conducted by two companies. One of these is the Boyle Concessions (Ltd.), and the other the Yukon Gold Co., the principal partners in which are the Messrs. Guggenheim. The Boyle Concessions (Ltd.) has taken over the holdings of the Canadian Klondike Mining Co., and controls and operates the properties of the Bonanza Basin Gold Dredging Co. and the plant of the Granville Power Co. The company has holdings on the Klondike Valley and other creeks, covering altogether about 40 square miles, and at present its operations are confined mainly to dredging the valley gravels. The Yukon Gold Co. has both dredgers in the valleys and hydraulic monitors at work in the upper white gravels.

The dredging process is an interesting and remarkable one, and produces curious effects. To wander up a lone glen with a mere trickle of water in it, and suddenly to come round a corner and confront a solitary large dredger, grinding away among peat bogs, wooden huts, and old dump heaps, is a surprising apparition to one who always associates dredgers with docks and navigable estuaries. But this is what can be seen in several creeks and dry gulches amid the Klondike hills. The plant is transported piecemeal, with great labor, to the patch of alluvium where it is required; a large square hole is then dug in the ground large enough to float the structure, and there it is put together, built up, and set agoing. The buckets scoop out the gravel at one end, and the stones and sand are dropped out in a bank behind at the end of a long conveyor, while the fine mud runs out by a separate orifice. This pond or tank is thus part of the working plant, and the dredger slowly carries along with it the water on which it floats, as the original stream is far too small to support the massive hulk. All the water in the stream is, of course, required to help in keeping the basin full, and to prevent its fluid from becoming too thick in consequence of the sediment that is being constantly washed out of the gravel.

The final result of the operation is that the flat bed of gravel as far down as the dredger buckets can reach—perhaps 60 feet at the outside—is cleaned out, and all sorted into a deposit of coarse shingle, with bowlders at one place and fine silt or sand at another. The gully, if narrow, after being robbed of its gold is thus left with a long embankment of stones, ribbed from side to side with deep furrows corresponding to each forward step of the dredger, and running up the glen in a serpentine course for miles, perhaps, like a moraine left by a valley glacier (pls. 2 and 6).

This "human moraine" heap entirely blocks up and interrupts the course of the original stream, and produces a series of more or less stagnant pools in the loops it makes in its meanderings between the sides of the gully. If the latter is broad, there may be two or three parallel embankments, with pools of muddy water between them, amid which the stream has to find its way past as best it can. The mud that is washed out in the process lodges in these lagoons and buries up the bases of the stony ridges. Plates 2 and 6 show this curious physiographic effect of the valley dredgers, an effect that will last for centuries, and one that has probably never been taken notice of before.

This, however, to anticipate matters, is not everywhere the final result of man's geological work on the Klondike River system.

First, the drift miners swarm in multitudes, like locusts, undermine the gravel, and turn it upside down. After they have disappeared the dredgers arrive and slowly plow it all over again, throwing it into great ridges of stones, with mud banks between. Finally, at those places where there are white gravels on the high ground, the hydraulic "giants" appear on the scene, wash them down in great cones of dejection vomited forth at intervals from the flumes on the mountain side. These white deltas radiate outward like fans, and sometimes reach across the entire valley, when they completely bury all that is below. By thus damming up gullies and producing new lakes they end in completely drowning and obliterating the effects of the previous dredging and drifting operations. When the geologist of the remote future comes to unravel these complex valley deposits he will have a tough problem before him, unless he has previously well acquainted himself with the achievements of the singular beings who inhabited these glens in a far-off age, when the hunt for yellow gold was apparently considered the ultimate aim and end of their whole existence. (See pl. 2.)

There are many dredgers of various sizes at work. The largest and newest, "Canadian No. 3," belonging to the Boyle Concessions (Ltd.), which started on March 31, 1913, was working close to Dawson City at the mouth of the Klondike Valley at the time of our visit. (See pl. 5.) It is an immense structure weighing some 2,000 tons ar cost nearly £100,000, but its efficiency is marvellous. It dredg 11,300 yards per day and goes Sunday and Saturday for 250 days year from March till nearly Christmas, when the weather becomes t severe. The buckets scrape all they can reach, including blocks of tl bedrock, and to test their efficiency we are told that a man twi threw a small coin about as large as a threepenny piece into the wate and each time it was brought up and recovered in the riffles along wi the gold. The whole machinery is controlled by one man, the dredg master, who has 10 men under him—3 winchmen who are paid (25s.) a day; three oilers, at $4.50 (18s. 6d.), and 4 deck hands, $4.80 (about 20s.). The winchmen and oilers work in three shifts 8 hours, and the deck hands two shifts of 12 hours. The cost dredging a cubic yard is 6 cents (3d.), and the average value of the go is 28 cents, so that the gross profit is 22 cents (11d.). On the 11,3 cubic yards dredged this gives a daily gross profit of a little over £50 so that it is obvious with gravel of this value there is a very handson annual return, and indeed it would pay well to dredge much poor stuff, of which no doubt there is still abundance.

We are often told by politicians of a certain class that wealth is tl result of manual labor only. Here we find a notable proof that suc shallow philosophy is based on a pure fallacy. The laborers got they could and wasted most of it. It was only when capital ar brains, and especially the latter, came to the rescue that the Klondil goldfield was saved from absolute extinction and granted a new ar prosperous lease of life.

The price of the dredger does not, however, nearly represent tl whole of the capital involved. The plant is worked by electric pow derived from the upper part of the Klondike River, as there is n nearly enough local fuel available for steam-raising purposes. Tl water is taken from the North Fork of the Klondike by the Granvil Power Co. and conveyed through a ditch 6 miles long to a point whe there is an effective head of 228 feet. By means of turbines and 10,000-horsepower plant the current is generated at 2,200 volts ar stepped up to 33,000 volts. It is conveyed over two main distributir lines, one of which runs down to the mouth of the Klondike River ar the other over the watershed to the basin of the Indian River. Th great installation supplies electricity, not only to the Boyle Co. dred ers, but to other public and private consumers in the district. there is neither cheap fuel nor water power in the immediate neighbo hood of Dawson City, it is obvious that this source of power and ligl is of the highest importance to the district.

The greatest achievement in the way of hydraulics is to be seen i the works of the Yukon Gold Co., an American firm belonging chiefl to Messrs. Guggenheim. As there are no local falls to provide wat for hydraulicking the higher white gravels, this company in 1905 initiated a bold scheme. After three years of very difficult work they succeeded in bringing water at high pressure from the Little Twelvemile River, a tributary of the Yukon with a good fall, from a point 64 miles from the Klondike placers. The water is conveyed in 37 miles of ditch, 15 miles of flume, and 12 miles of pipe line, crossing five depressions, including the Klondike Valley, mainly by means of inverted syphons. The water is delivered to the Bonanza terraces under a head of 500 feet. The total length of this waterway and its extensions is 75 miles, and the stream issues from the nozzles at a pressure of 100 pounds per square inch or more.

The "giants" or "monitors," as they are called at some places in America, throw the water against the frozen cliff, and it takes some time to make an impression on a block of the white icy conglomerate, as I soon found when I tried my hand at it. Every day in summer some of the face crumbles away as the ice melts, but the parts that are hard frozen are not quickly eroded down by the powerful jet that is concentrated on them.

The gravel and bowlders are washed into steep and narrow cuts or ravines sunk in the rock floor of the terrace, with mouths opening on the steep hillside. The gold is caught in wooden flumes and sluice boxes through which the tumultuous current rushes before it spouts out on the face of the slope and is discharged into the gully in the way I have already described. The hydraulicking of these high gravel cliffs with vast jets of snow-white water, like graceful comets, is the most picturesque and striking spectacle in the whole district. (See pl. 5.)

The last of the seven systems of gold working, the mining of the quartz reefs from whose decay the placer gold has been derived, is not important. No large veins have been discovered, but more prospecting may yield some fruits in the future after other methods have been exhausted. On our way down from the Dome we stopped at Victoria Gulch, a small branch near the top of Bonanza Creek, where a prospectors' four-head battery, worked by electric current from the Granville power line, was crushing ore from an open-cast mine about 1,000 feet up the hillside. The Lone Star mine is in a considerable body of low-grade ore in mica schist full of quartz lenticles. It appeared to be about 200 feet wide, but its dimensions were not well defined. The ore did not average more than $3 a ton in value, but assays had proved that at places it contained over 2 ounces per ton, and the prospectors said they were able to pay their way from the proceeds.

The hillsides are covered with scrubby vegetation growing on the decomposed and crumbling rock, and thus the outcrops of mineral lodes are not always easily discovered. From the quantity of gold in the gravels which are derived from the parts of the local rock surface that have been denuded away, it is likely that the undecomposed rock beneath contains much more, but unless lodes are found in a sufficiently concentrated form at any one place they can not be profitably mined. Hitherto the attention of miners has been mainly directed to what is immediately payable, but further research may reveal large bodies of pay ore in the little explored district. The great and highly profitable Alaska Treadwell mine on the coast near Juneau has laid open an immense body of low-grade ore, but the conditions are far more favorable for cheap mining than they are likely to be at Dawson for a long time to come.

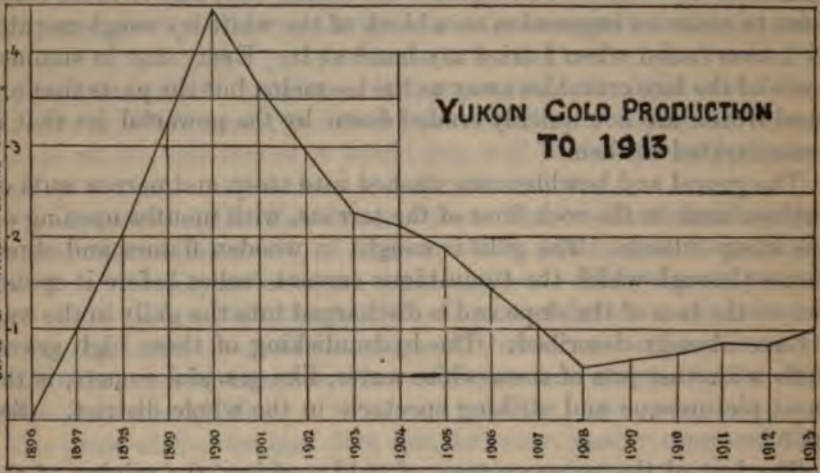
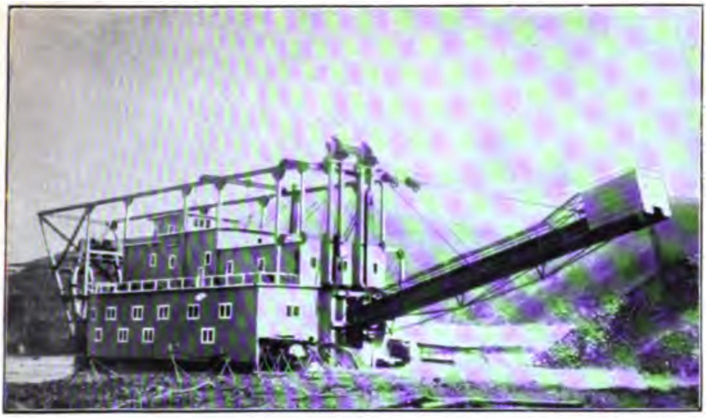


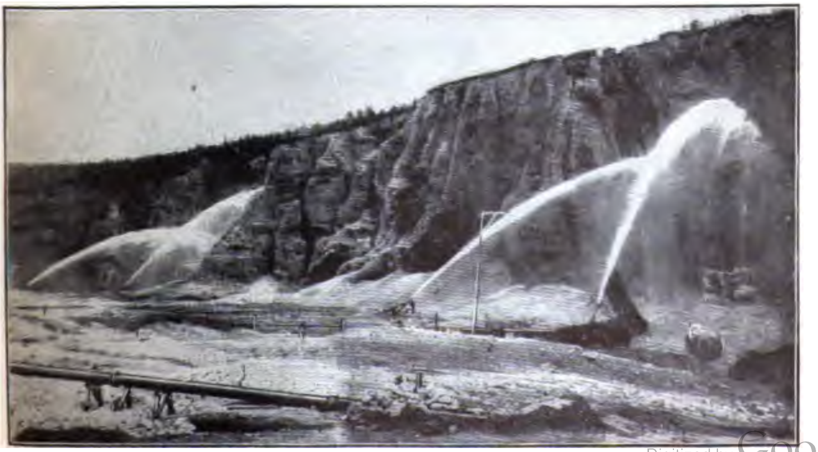
FIG. 5.—Yukon gold production to 1913.

In conclusion it may be noted that although the Yukon and Klondike district is not now producing sensational results, the production from the placers is still large and steady. The exact annual production prior to 1904 is only estimated, but the figures from that year are officially known and have been kindly supplied me by Mr. Edmund E. Stockton, the inspector at Dawson. The Government levies a royalty of 2 per cent on the value of the gold. This is carefully collected, sometimes with the help of that admirable force, the Northwest Mounted Police (mainly recruited in the Old Country) who work more "for honor and applause" than for financial reward, and have, with a small but highly efficient and thoroughly respected personnel, been the means of maintaining a wholesome respect for British law and order in the vast Northwest territory during and since the very trying time of the first great rush of wild adventurers to the Klondike.

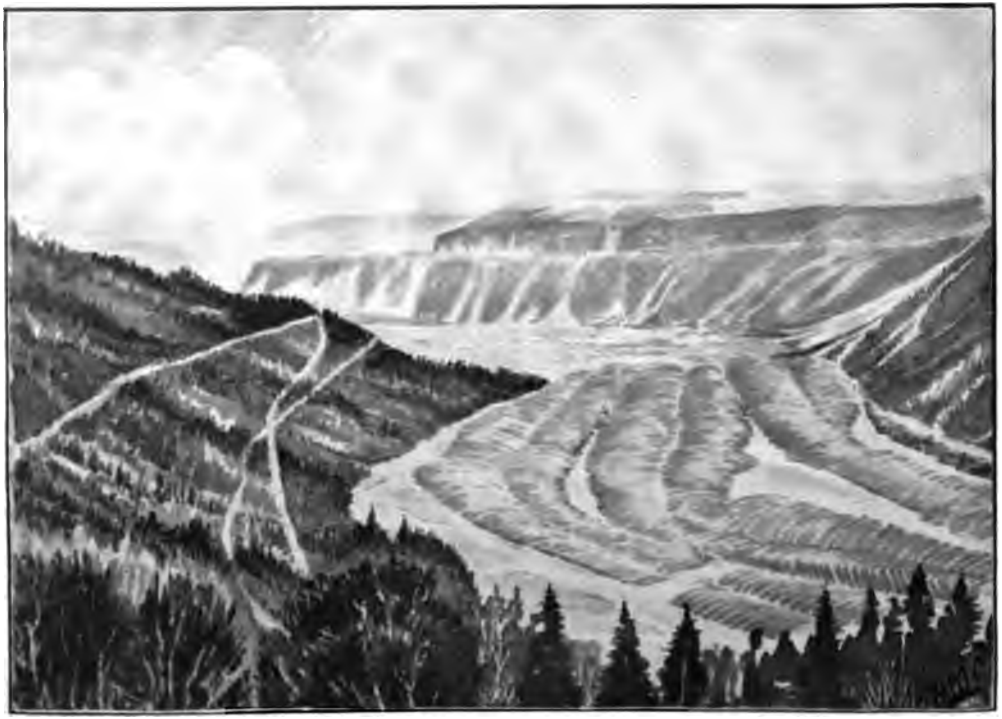


THE LARGEST DREDGER AT KLONDIKE IN 1913.

KLONDIKE RIVER, SHOWING DREDGERS AT WORK.



HYDRAULICKING ON LOVETT GULCH.



EFFECT OF GOLD DREDGING, BONANZA CREEK, KLONDIKE.

The gold production from 1898 to 1913 was as follows. The first column is in dollars and the second is the approximate value in pounds sterling, reckoning £1 as roughly equal to $5. The years in question end March 31.

Yukon gold production.

1898........	$10,000,000=	£2,000,000
1899........	16,000,000=	3,200,000
1900........	22,275,000=	4,455,000
1901........	18,000,000=	3,600,000
1902........	14,500,000=	2,900,000
1903........	12,250,000=	2,450,000
1904........	10,500,000=	2,100,000
1905........	9,306,675=	1,861,335
1906........	$7,166,617=	£1,433,323
1907........	5,141,136=	1,028,227
1908........	2,820,131=	564,026
1909........	3,260,364=	652,073
1910........	3,594,893=	718,978
1911........	4,125,570=	825,114
1912........	4,024,245=	804,849
1913........	5,018,411=	1,003,682

The largest year's output was in 1900, and was estimated at $22,275,000 (£4,455,000), and the total output of the territory since the discovery of gold is estimated at over $150,000,000 (£30,000,000).

These figures, which show the rapid rise and steady decline of the production and the slow increase since 1908 after hydraulicking and dredging operations began, may be made more impressive by reference to figure 5.

The important question may now be asked: How long is the field likely to remain productive? This aspect of the subject has been discussed by Mr. McConnell in a report published by the Geological Survey in 1907. The total volume of the remaining river and terrace gravel beds was measured and the deposits were carefully sampled in sections. Mr. McConnell's conclusion at that time was that after 1906 the total value of the gold in the Bonanza and Klondike valleys and their tributary creeks was $53,642,620. Since then the value of gold obtained up till the spring of 1913 was $27,984,750, so that of the amount estimated there remained of gold values after 1913 only $25,657,800 still to be produced.

The production in 1913, as shown above, was a little over $5,000,000, and since then the large dredger of the Boyle Concessions has added to the productive capacity of the plant. If Mr. McConnell is right in his figures and no fresh discovery is made, the field at this rate will be quite exhausted in five years' time. But Mr. Boyle has carefully sampled the river gravels at the mouth of the Klondike by boring, and there is evidence that the capacity of the field is considerably greater than Mr. McConnell anticipated. Of course, the life of the field will be shortened in proportion to the rate at which it is being exhausted, and when all the alluvial gold is extracted the main hope for Dawson City will be the discovery of reefs or bodies of payable ore in the bedrock.

The discovery of gold was the principal means of opening up the Yukon district for settlement and showing that its resources are not entirely dependent on the yellow metal. The vast territory is imperfectly explored, and although it is far north, the climate is warm and favorable for agriculture and grazing in summer. Further exploration is now much easier from such a good center as Dawson City than it was 15 years ago, and we may hope that fresh enterprise will not fail in revealing new resources that will lead to the permanent settlement of this remote and almost uninhabitated outpost of the Dominion.

THE HISTORY OF THE DISCOVERY OF SEXUALITY IN PLANTS.[1]

By Prof. DUNCAN S. JOHNSON.

From the beginning of man's thoughtful consideration of natural processes, the phenomenon of sexual reproduction, with the associated phenomena of heredity, have persistently engaged his keenest interest. The primary fact of the necessary concurrence of two individuals in the production of offspring in the case of animals was recognized from the beginning. The equivalent phenomenon was not established for plants until the end of the seventeenth century. At this time, however, little more was known of the essential features of the sexual process in animals than had been familiar to Assyrians, Egyptians, and Greeks 20 centuries before.

Of the additions made since 1700 to our knowledge of sexual reproduction, of its varied types and of the associated phenomena, no mean share has been contributed by botanical investigators. Noteworthy among such contributions are the work of Koelreuter and Mendel in the production and systematic study of plant hybrids, and the early work of Pfeffer on the chemotactic response of spermatozoids. Of more recent work we may cite that of the plant cytologists on apogamy and apospory, on multinucleate sexual cells or gametes and on the long-delayed nuclear fusion in the sexual reproduction of the plant rusts. It should then be of interest for us to consider just how and when the more important steps have been taken in building up the vast mass of somewhat incomplete knowledge that we now possess concerning the reproductive process in plants. Because of exigencies of time and patience, I shall confine myself primarily to an attempt to picture the chief steps by which our present knowledge of the essential sexual process, the mingling of two parental substances, has been attained. Incidentally we may note the changes in point of view of investigators and in their mode of attack on this problem. I shall attempt to suggest the trend of development more clearly by often grouping the chief phenomena discovered in such a way as to indicate the sequence of discovery within each group of the different phases of the sexual process, though the order of discussion may thus not always accord with the sequence of the discovery of individual phenomena in plants as a whole.

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[1] Address of the vice president and chairman of section G, Botany, American Association for the Advancement of Science, December, 1913. Reprinted by permission of author. Printed in Science, Feb. 27, 1914.

In following the evolution and change in aspect of our problem we shall often find it best to keep a few relatively great names prominent. This will serve in the first place to make the story more vivid and intelligible. It will at the same time often come nearer the essential truth, for in each great forward step some one worker has usually been the dominating leader.

I.—THE DISCOVERY THAT POLLINATION IS A PREREQUISITE TO SEED FORMATION, 750 B. C. TO A. D. 1849.

The first discoveries pointing to the existence of sex in plants were evidently made very early in human history by peoples cultivating unisexual plants for food. The existence of fertile and sterile trees of the date palm was known to the peoples of Egypt and Mesopotamia from the earliest times. Records of the cultivation of these trees and of artificial pollination have come down to us on bas-reliefs from before 700 B. C., found in the palace of Sargon at Khorsabad (Haupt and Toy, 1899).[1] The Assyrians, it is said, commonly referred to the two date trees as male and female (Rawlinson, 1866). The Greeks, in spite of their peculiarly keen interest in natural phenomena, failed to offer any definite interpretation of this well-known fact concerning the date palm. Aristotle and Theophrastus report the fact, gained apparently from the agriculturists and herb gatherers, that some trees of the date, fig, and terebinth bear no fruit themselves, but in some way aid the fertile tree in perfecting its fruit. But without recording a single crucial experiment on the matter Theophrastus concludes that this can not be a real sexuality, since this phenomenon is found in so few plants.

In this uncertain state the knowledge of sexuality in plants was destined to rest for 20 centuries, waiting for the experimental genius of Camerarius to give a conclusive answer to the question raised by the Assyrian and Greek gardeners and answered wrongly by Theophrastus. The English physician Grew (1676) did, it is true, accept and expand the suggestion of Sir Thomas Millington that the stamens serve as the male organs of the plant. Thus Grew concludes (p. 173) that when the anther opens, the "globulets in the thecæ act as vegetable sperm which falls upon the seed case or womb and touches it with prolific virtue." But this guess, though it proved correct in the main point, was still a guess and not supported by any critical evidence so far as recorded by Grew. The only adequate evidence that could be obtained on this question, while microscopes and technique were so imperfect, was experimental evidence. This kind of proof was first given some 20 years after

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[1] Dates herein indicate publication of discovery. See bibliography appended to present article in *Science, Feb. 27, 1914.*

Grew's work by Rudolph Jakob Camerarius, of Tübingen. Camerarius fully appreciated the presence of a real problem here. He also had the genius to see that the philosophical attempts of many of his immediate predecessors to discover its solution entirely in their own inner consciousnesses were futile. With the insight of a modern experimenter Camerarius put the question to the plants themselves. The results of his experiments, as reported in the famous letter of 1694 to Prof. Valentin, of Giessen, were clear and conclusive. After noting that the aborted seeds were produced by isolated—and therefore unpollinated—female plants of Mercurialis, and of mulberry, by castrated plants of the castor bean, and by plants of Indian corn from which he had removed the stigmas, Camerarius gives his interpretation of these phenomena. He says (Ostwald "Klassiker," p. 25):

> In the vegetable kingdom there is accomplished no reproduction by seeds, that most perfect gift of nature, and the usual means of perpetuating the species, unless the previously appearing apices of the flower have already prepared the plant therefor. It appears reasonable to attribute to these anthers a nobler name and the office of male sexual organs.

In the 70 years after Camerarius had proved in this way the existence of two sexes, and the fertilizing function of the pollen in plants, little advance was made. Bradley, of London, Gleditsch, of Berlin, and Gov. Logan, of Pennsylvania, confirmed parts of Camerarius's work, and the great Linnæus accepted the conception of the stamens and pistils as sexual organs as clearly proven, not, be it noted, by the results of Camerarius's experiments, but by the "nature of plants."

In 1761 J. G. Koelreuter, of Carlsruhe, published an account of the first systematic attempt that had been made, with either plants or animals, to produce and carefully study artificial hybrids. In his work with hybrid tobaccos, he demonstrated that characters from both parents are often associated in a single offspring. He thus not only completed Camerarius's work, but also, by showing that the male parent participates in the makeup of the offspring, he helped materially to break down the "emboitement theory" of Christian Wolff, which assumed that the embryo came entirely from the egg, and that its characters could not be influenced by the male parent. It is true that Koelreuter was mistaken in believing that fertilization is accomplished by the mingling of the oil on the pollen grains with the secretion of the stigma to form a mixed fluid, which he supposed then penetrated to the ovule. Nevertheless, his conception of the mingling of two substances was a move with the proper trend.

Koelreuter also demonstrated that in nature the pollen necessary to fertilization is often brought to the stigma by insects. He thus opened up a field of research which was cultivated with such splendid effect by Konrad Sprengel 30 years later, and by Darwin, Müller, and others a century afterwards.

In spite of the absolutely conclusive work of Camerarius, Koelreuter, and Sprengel on the sexuality of plants, their conclusions were often rejected during the first half of the nineteenth century. Thus certain devotees of the nature philosophy occupied themselves either in proving over again, after Cesalpino, that plants can not be sexual because of their nature, or in trying, by ill-conceived and carelessly performed "experiments," to prove the conclusions of Camerarius and Koelreuter erroneous. These objectors were finally silenced, however, when Gaertner, in 1849, published the results of such a large number of well-checked experiments, entirely confirming the works of Camerarius, Koelreuter, and Sprengel, that no thinking botanist has since doubted the occurrence in flowering plants of a sexuality essentially identical with that found in animals.

II.—THE DISCOVERY OF THE POLLEN TUBE AND ITS RELATION TO THE ORIGIN OF THE EMBRYO, 1823–1847.

During the opening years of the nineteenth century a number of botanists, who believed in the sexuality of plants, tried to discover by the aid of the microscope just how fertilization is effected. Most botanists of the day believed the pollen grain burst on the stigma, and that its granular contents found a way through the style to the ovary. An entirely new aspect of the problem of fertilization was opened up, however, when in 1823, Amici, of Modena, saw on the stigma of Portulacca young pollen tubes arising from the pollen grains. Seven years later he followed these tubes through the style to the micropyle of the ovule. At about this time also, Jakob Matthias Schleiden (1838) took up the study of this same problem. He was a man of vigorous intellect and great versatility, who sometimes misinterpreted what he saw, but who proved a most stimulating opponent to a number of other workers who did observe accurately. After denying Robert Brown's assertion that the pollen tubes of the orchids arise in the ovary, Schleiden proceeded to describe and figure the pollen tube as penetrating not merely the style and then the micropyle, but even far into the embryo sac itself.

Here, as he says in his Grundzüge (II, p. 373):

> The end (of the pollen tube) soon swells, either in such a way that the vesicle arising in it fills the whole cavity of the portion of the tube within the embryo sac, or there is left, between the apex of the embryo sac and the embryonal vesicle of the tube, a long or a short cylindrical portion of the latter, the suspensor.

He thus regarded the embryo sac as a sort of hatching place for the embryo, which he thought formed from the end of the pollen tube. This idea of the origin of the embryo really denied the occurrence of any actual sexual process, and made the pollen the mother of the embryo.

In 1846, however, the error of this conception was clearly demonstrated by Amici, who showed that the embryo of the orchids arises from an egg which is already present in the embryo sac when the pollen tube reaches it. It is this preexisting egg, according to Amici, that is stimulated to form the embryo by the presence near it of the pollen tube. This view was confidently supported by Mohl (1847) and Hofmeister (1847), and the controversy with Schleiden became even more spirited. As Mohl afterwards wrote (1863), men were "led astray by their previous conceptions to believe they saw what they could not have seen." The dispute even approached the acrimonious, as when Schleiden (1843) says of one worker's figures, "Solche Praparate sind ohne Zweifel aus den Kopf gezeichnet."

Hofmeister, from the beginning of his study of fertilization in seed plants, had sought in the pollen tube for some equivalent of the spermatozoids, those motile male cells of the mosses and ferns that had first been understood by Unger in 1837. He was unable, however, to do more than point out the mistake of earlier observers in regarding the starch grains of the pollen tube as spermatozoids, and to suggest the likelihood that these motile cells might be discovered in the gymnosperms, a prediction the fulfillment of which was realized by Ikeno and Webber 50 years later. In his study of pollen tubes Hofmeister demonstrated to his own satisfaction that the tube does not open in accomplishing fertilization. His view, which was the one current till 1884, was that the egg is stimulated to develop into the embryo by some substance that diffuses through the imperforate wall of the pollen tube.

III.—THE DISCOVERY OF A PROTOPLASMIC FUSION AT FERTILIZATION.

We come now to consider a series of discoveries of supreme importance in the investigation of the essential sexual process in plants. This is the period in which the problem that had baffled naturalists for twenty centuries was at last solved, at least in one most essential feature, by the demonstration of the occurrence at fertilization of a mingling of paternal and maternal substances.

It will not be without interest at this point to note the intellectual stimuli which led an unusual number of workers to investigate this phase of our problem.

In the first place, there were on record and under discussion at the middle of last century the many puzzling observations of the "spiral faden," or animalculæ, as they were thought to be, that had been found arising from a number of plants. These motile, spiral filaments had been seen in a liverwort (Fossombromia) by Schmiedel (1747), in Sphagnum by Esenbeck (1822), in Chara by Bischoff

(1828), and finally, on the fern prothallus by Naegeli (1844). Unger (1834–37) studied these bodies in the mosses (Sphagnum and Marchantia) and declared his belief that they are not infusoria, but are the male fertilizing cells. At this time also the zoologists of the day were making the first detailed studies of the spermatozoa of animals. Barry (1844) had seen a spermatozoön within the egg of the rabbit; Leuckart (1849) saw them enter the frogs' egg, and then, in 1851, Bischoff and Allen Thompson proved that fertilization is accomplished by the actual entrance of the spermatozoön into the egg. A no less important influence, in stimulating the botanical workers on the problem of fertilization, was the magnificent work of Hofmeister, on the reproductive structures of the mosses, ferns, and conifers. By these splendid researches he had indicated to men of less insight, and less comprehensive imagination, just the points in the life cycles of plants where the critical phases of the reproductive process are to be sought.

Among the many workers engaged on this problem of fertilization in plants in the third quarter of last century there was, in consequence of readier exchange of information, an attitude of greater consideration for the work of other investigators than was found in the two preceding decades. There were differences of opinion and interpretation, to be sure, but there was less of that strenuous cocksureness when men saw, or thought they saw, differently from others. The mistakes of the brilliant Schleiden were perhaps remembered. Men like Hofmeister, Pringsheim, and Strasburger added to and modified the interpretations of other workers in the same spirit with which they remolded their own immature conclusions. There was a spirit of cooperation evident; it became possible for a worker to observe and record the fate of a pollen tube in good temper and with calm judgment.

The first steps toward the demonstration of a union of two masses of living substance at fertilization resulted from the study of a group of plants, the algæ, in which sexuality had not been proven or generally admitted. It had, however, long before been suggested in the case of Spirogyra by Hedwig (1798) and Vaucher (1803).

The algæ were in fact especially advantageous for the study of fertilization, since the development and behavior of the reproductive organs and cells could, without elaborate preparation, be readily seen under the microscope, and often followed through in living material. Thus, Thuret, in 1853, for the first time saw the active sperms attached to the egg of Fucus, and, in 1854, proved experimentally that only eggs to which spermatozoids have had access will germinate. He thus demonstrated in this alga the correctness of Unger's unsubstantiated surmise (1837) that the spermatozoids are the male fertilizing cells. In Œdogonium, Pringsheim, in 1856 (p. 9), watched the spermatozoid push into the receptive tip of the living egg and saw the characteristic oöspore wall formed in consequence. This, except for the less satisfactory observations made on Vaucheria a year previous by the same worker, is the first case recorded of the observation of the actual union of male and female cells in any plant. Such a union of the protoplasmic masses of the two sexual cells was soon shown to be a characteristic feature of fertilization in a number of algæ. Thus De Bary saw it in Spirogyra (1858), and Pringsheim (1869) repeatedly observed the gradual fusion of the motile gametes of Pandorina. It was nearly 30 years later, however, that this phase of fertilization was first seen in seed plants by Goroschankin and Strasburger.

The workers on this problem were on the lookout for further details of the process of fusion, and even knew rather definitely what they were looking for, but failed to discover it from lack of proper methods of preparation of material. Thus, Strasburger, in 1877, carefully studied the process of conjugation in Spirogyra and found that "Hautschicht fuses with Hautschicht, Kernplasma with Kernplasma"—"The chlorophyll bands unite by their ends"—and he then goes on to say of the feature that evidently interested him most, "the cell nuclei of both cells, however, became dissolved; the copulation product is without a nucleus." Two years later Schmitz (1879), when studying hematoxylin-stained material of this alga, was more fortunate. He saw the two nuclei in the zygote, as he says, "approach nearer and nearer, come into contact and finally fuse to a single nucleus." This observation by Schmitz is an important one, for in it we have the first clear statement that the nucleus of the male cell passes over intact to the female cell, there to fuse with the female nucleus.

Strasburger had, it is true, seen a second nucleus fusing with that of the egg in the archegonia of Picea and Pinus in 1877. He did not, however, really know the source of this second nucleus, though he suspected some relation to those that are present earlier in the tip of the pollen tube. These tube nuclei he says are dissolved just before fertilization, and then just after fertilization, to quote (1877):

> The male nucleus formed from the contents of the pollen tube is found now near the end of the tube, now near, or in contact with, the egg nucleus. * * * The protoplasmic contents of the pollen tube, I hold, passes through the (imperforate) tube-membrane in a diosmotic manner.

The fertilization of the gymnosperms, because of their large eggs, pollen tubes, and nuclei, was at this time being studied by a number of workers. One of these, Goroschankin, in 1883, was able to demonstrate that in *Pinus pumilio* the pollen tube opens at the end, and that through this pore the two male cells pass bodily into the egg. Goroschankin's mistake, in supposing both male nuclei to fuse with the egg nucleus, was corrected by Strasburger the following year. The latter (1884) saw the same bodily exit of both male nuclei from the open pollen tube of Picea, but found only one male nucleus fusing with that of the egg. In the same publication Strasburger also records numerous instances in which he had been able to observe the same mode of escape of the contents of the pollen tube into the ripe embryo sac in angiosperms. At last, as Strasburger puts it, in discussing fertilization in the conifers:

> The most important morphological facts are clear. It is established that the male nucleus that copulates with the egg nucleus, passes as *such* out of the pollen tube into the egg.

Thus, finally, was the actual material contribution of both parents to the embryo of the seed plants first seen. This was just two centuries, lacking a decade, after Camerarius (1694) had proven that the presence of pollen on the stigma is indispensable to seed formation. One chief reason why this important problem so long baffled all investigators was the lack of proper methods of preparing material for study. The older method of studying unfixed and unstained sections had certain advantages, it is true. The sequence of developmental stages was often determined with certainty by actually following their succession in living material under the microscope, and there was less cause also for dispute about artifacts. But structures of the same refractive qualities were not readily distinguished in such sections. As Strasburger himself says (1884, p. 18):

> The negative results of my earlier studies and of those of Elfving were due to the lack of a method which permitted the nuclei to be distinguished in the strongly refractive contents of the pollen tube up to the moment of fertilization.

That these studies of 1884 were successful was largely due to the use of material fixed in five-tenths per cent acetic acid, 1 per cent osmic acid or in absolute alcohol, and stained in borax carmine, hematoxylin or iodine green.

The extreme significance of the fact that those most highly organized portions of the cell substance—the nuclei—were so prominent in the process of fertilization was at once appreciated by Strasburger, who in 1884 (p. 77) announced the following general conclusions as the outcome of his consideration of the phenomena observed:

> (1) The fertilization process depends upon the copulation with the egg nucleus of the male nucleus that is brought into the egg, which is in accord with the view clearly expressed by O. Hertwig. (2) The cytoplasm is not concerned in the process of fertilization. (3) The sperm nucleus like the egg nucleus is a true cell nucleus.

In the years since 1884 the nuclei have been found to be the structures chiefly concerned in fertilization, whenever such a process occurs. Among the earlier observations of this nuclear union at fertilization in each of the great groups are the following, named in the order of discovery: It was seen in Pilularia (Campbell, 1888), in Riella (Kruch, 1891), in Œdogonium (Klebahn, 1892), in the plant rusts (Dangeard and Sapin-Trouffy, 1893), in the toadstools (Wager, 1893), in the red alga Nemalion (Wille, 1894), in Sphærotheca (Harper, 1895), in the rockweed, Fucus (Farmer and Williams, 1896). Finally Zederbauer (1904) reported it for the Peridineæ, and Jahn (1907), Olive (1907), and Kraenzlin (1907) made it out in the myxomycetes.

The observations just referred to, and many others on plants in all groups, warrant the general application of Strasburger's conclusion that a nuclear union is the characteristic feature of every sexual process. The few cases where the male cytoplasm seems more prominent than usual, as in the three conifers studied by Coker (1903), Coulter and Land (1905), and Nichols (1910), can not yet be said to have rendered it very probable that this cytoplasm plays a primary part as an inheritance carrier.

IV.—THE DISCOVERY OF THE ALTERNATION OF GENERATIONS IN PLANTS, 1851.

The fact that the sexual cells of the higher plants are produced on a plant body or individual distinct from that which forms the asexual reproductive cells, and that in the normal life cycle the one type of individual arises from, and later gives rise to, an individual of the other type, must be regarded as one of the most significant features of the evolution of plants yet discovered. One of the chief general results of the magnificent work of Hofmeister was the discovery of this regular alternation of a sexual and an asexual generation, not only in the life history of the mosses and ferns, but also in that of the seed plants. Hofmeister states this result clearly in the Vergleichende Untersuchungen, and makes it apply still more broadly in a brilliant generalization published in the Higher Cryptogamia. There he says (p. 439):

> The phenogams, therefore, form the upper terminal link of a series, the members of which are the Coniferæ and Cycadeæ, the vascular cryptogams, the Muscineæ and the Characeæ. These members exhibit a continually more extensive and more independent vegetative existence in proportion to the gradually descending rank of the generation preceding impregnation, which generation is developed from reproductive cells cast off from the organism itself.

Since Hofmeister's day detailed investigations by many workers have fully confirmed Hofmeister's conclusion. They have shown the essential homology, not only of the spore-producing organs, and the one or two kinds of spores produced in them, but also of the structures arising from these spores, throughout all cormophytes, from the mosses upward.

In the studies of the algæ that followed immediately after Hofmeister's work, investigators of these plants sought in them for some evidence of that regular alternation of sexual and asexual phases that had been demonstrated in higher plants. Pringsheim (1856, p. 14) one of the ablest of these students of the algæ, at first regarded the multicellular body, formed at the germination of the oospore of Œdogonium and Coleochæte, as an asexual phase comparable with the simple sporophyte of the liverwort Riccia. Celakowsky (1886) distinguishes as *homologous* alternation those cases, in algæ like Ulothrix or Œdogonium, where the gamete-producing generation seemed capable of zoospore production also. The constant and regular alternation of the archegoniates and seed plants he called *antithetic* alternation. Pringsheim (1877) found that moss protonemata form from cuttings of the seta of the sporophyte as well as from bits of the gametophyte. From this fact, and from Farlow's discovery (1874) that a sporophyte of the fern, *Pteris cretica*, may arise directly from the prothallus, without the fertilization or even the formation of an egg, Pringsheim concluded that both generations of the archegoniates are really identical. He says (1877), p. 6:

> I believe the moss sporogonium stands to the moss plant in the same relation that the sporangium-bearing Saprolegnias do to the oogonium-bearing plants of this species, . . . I therefore turn against this interpretation of the fruit generation of the thallophytes in general, and especially against this interpretation of the sexual shoot generation of the Florideæ and Ascomycetes . . . The cystocarp is evidently not a separate individual but part of the sexual plant that produces it.

The antithetic view was reasserted, however, especially by Celakowsky (1877) and Bower (1890), both of whom emphasized the suggestion of A. Braun (1875) that the sporophyte is a new thing phylogenetically. Bower holds that the types of sporophyte found in the archegoniates have arisen by the amplification of the zygote, with the sterilization for vegetative functions of smaller or larger portions of the originally all-pervading sporogenous tissue. The amphibious type of alternation of the mosses and ferns has arisen, according to Bower's conception, with the migration of these plants to the land, and the assumption of the terrestrial habit by the sporophyte. The antithetic view was also supported in a most striking way, later, by the results of the workers on chromosomes.

The homologous view of alternation also has not been without supporters in the years since Pringsheim. One of its upholders, Klebs (1896), based his belief on the fact that he could determine the type of reproductive cells formed by the algæ Hydrodictyon and Vaucheria, by changing the conditions under which they are grown. Lang (1896–1898) favored the homologous view because of the discoveries of Farlow, De Bary, Bower, Farmer, and himself on apogamy and apospory. Scott, one of the strongest advocates of the homologous alternation theory, bases his belief not only on the evidence afforded by the cases of apogamy and apospory, but also on the fossil record. He points out the lack of any sporophyte, living or fossil, that can be regarded as ancestral to that of the ferns. In arguing for the homologous origin of the leafy fern sporophyte from a liverwort-like thallus Scott says (1911):

> We know plenty of intermediate stages between a thallus and a leafy stem; but no one ever saw an intermediate stage between a sporogonium and a leafy stem.

V. THE DISCOVERY OF CHROMOSOME REDUCTION AND OF SYNAPSIS, 1888.

We have seen that during the two decades at the middle of last century students of sexuality in plants devoted their attention to the discovery of the relation of the pollen tube to the origin of the embryo. The three decades after 1860 were given largely to the proof of a union of a paternal with a maternal nucleus as a constant feature of the sexual process in plants. For the past two decades workers interested in reproduction have been engaged especially in determining the behavior and fate, in the various phases of plant development, of those essential elements of the nuclei, the chromosomes. The result of this study has been to give us a much more definite criterion than we had before of just what constitutes a sexual process. Moreover, this intimate examination of the chromosomes, together with the precise means of germinal analysis by breeding, introduced by Mendel, has given us some insight into the significance of the sexual process in the ontogeny and phylogeny of plants.

The discovery of chromosomes in plants may best be attributed to Strasburger, who, in 1875, first figured them distinctly in the embryo of Picea. It is true that Hofmeister (1867) had noticed the equatorial plate of "albuminous clumps" in cells at the time of their division, and Russow (1872) saw, in the dividing spore mother-cell nuclei of Ophioglossum, plates of vermiform rods ("Stäbchenplatten"). Strasburger (1879), and Hanstein (1880), and Flemming (1880) were, however, the first to realize the constancy of the occurrence of chromosomes in the dividing plant nucleus. The fact soon pressed itself upon the investigators that the number of these chromosomes differs in different plants and in different phases of the same plant. Then followed the epoch-making discovery of the zoologist Van Beneden (1883), that the number of chromosomes in the egg and sperm of the thread worm Ascaris is the same, and that the double number characteristic of the body cells becomes reduced during the maturing of the germ cells. Botanists after some delay, due, as Strasburger says, to lack of proper technique, succeeded in demonstrating these same facts for plants. Thus Strasburger in 1888 showed that the number of chromosomes characteristic of the egg and of the male nucleus in a number of angiosperms is the same, and is fixed by a reduction occurring in the mother cells of the pollen and of the embryo sac. Guignard also (1889 and 1891) demonstrated these phenomena in Lilium and in the pollen mother cells of Ceratozamia, noting the eight double chromosomes in the latter and other peculiarities of the first mitosis. Overton (1893) counted the same number of chromosomes in the female prothallus of Ceratozamia, while Farmer (1894) found four chromosomes in the thallus and sexual reproductive cells of Pallavicinia, and eight in the seta and capsule.

Later in the same year Strasburger, in a masterly address before the British Association, completed the proof of Overton's suggestion (1893) that in the mosses and ferns also reduction takes place, as Overton puts it, "in the mother cells of the spores; that is, at the point of alternation of the generations." Strasburger, by comparing his counts of chromosomes in the dividing spore mother cells of Osmunda with the number seen by Humphrey (figures published in 1895) in the tapetal cells, found the latter number about double. It is interesting to note also that the Osmunda slides used in this work were among the first paraffin sections used by Strasburger.

From this correspondence of the liverwort and fern mentioned with the seed plants in which reduction had been seen, Strasburger was led to predict the universal occurrence of this phenomenon of reduction in all plants that reproduce sexually. Concerning the phylogenetic origin of the reduction process Strasburger held that all plants (and animals) were primitively nonsexual and had a constant number of chromosomes. With the development of sexual reproduction the initiation of the process of chromosome reduction avoided the evident disadvantage of repeated doubling of the chromosome number at each sexual fusion. This return from the double number formed in the zygote to the primitive ancestral number of chromosomes he believed might occur at any point in the life cycle before the next fertilization. Strasburger then went on to emphasize the advantage of the sexual mode of reproduction, when once acquired, in allowing new combinations of parental strains in the offspring, and the disadvantage it had of producing so small a number of offspring. It is to meet this disadvantage, he suggested, in agreement with Bower, that the zygote of forms like Coleochæte, mosses, ferns, and seed plants took over the function of multiplying the progeny by a sort of polyembryony—the formation of spores. The spore-bearing generation later in the evolutionary history became ultimately independent of the gametophyte, and at a still later period it not only produced two kinds of spores but also assumed the care and nutrition of the reduced female plant arising from the larger of the two kinds of spores. Thus, in Strasburger's view, the primitive nonsexual generation is now represented in the archegoniates by only the sexual phase, which has gradually lost its power of asexual multiplication, while the sporophyte is a third, a new generation which has risen by specialization of the zygote. There is in the cormophytes then an antithetic alternation of the two most recently evolved phases of the life cycle, while the only clear trace of the primitive nonsexual phase is found in the halved number of chromosomes, which is reverted to by a process of chromosome reduction at some point in each life cycle.

In the two decades since this famous pronouncement of Strasburger's was made, chromosomes have been counted in the different developmental phases of nearly all groups of plants. These counts have shown that wherever there is sexual fusion there is also, at some other point in the life cycle, a reduction of the double number of chromosomes so formed to the single number characteristic of the gametes. In all cormophytes and many thallophytes this reduction occurs at sporogenesis.

The investigation of the complementary phase of the chromosome behavior, the doubling of the number at fertilization, has during the past two decades also led to extremely interesting results.

The earlier workers on sexual nuclear fusion apparently believed that the paternal and maternal nuclear materials became intimately mingled soon after contact of the nuclear walls. Thus Klebahn (1892) described the chromatin nets of the two nuclei as gradually merging into one in Œdogonium, and Shaw (1898) described the same process in Onoclea. It is true that Guignard (1891) had noted that, in Lilium and Fritillaria, the male and female reticula remain distinct until the prophase of the first nuclear division of the embryo. Later research, however, showed that the paternal and maternal components remain distinct till much later than this; in fact, that the chromatin elements from the two parents do not really fuse at all during the process of fertilization. On the contrary, it seems quite likely that all through the development of the sporophyte the chromosomes from the two sources retain their identity and individuality.

Thus Blackman (1898) and Ferguson (1901) say that in the fusing nuclei of Pinus the two chromatin nets never lose identity, and that at the first mitosis of the embryo each constituent gives rise to its own group of chromosomes. This independence of the two chromatins at fertilization has since been seen in a number of species, and it is now believed to persist throughout the life of the sporophyte. The double number of chromosomes is present at each mitosis of this generation, and these chromosomes sometimes occur in pairs and are assumed to consist of a paternal and a maternal chromosome each. In certain plants also, according to Overton (1909), Gregoire (1910), Stout (1912), and others, the individuality of the chromosomes of the resting nucleus, postulated by Strasburger in 1894, is morphologically discernible. De Vries (1903) emphasized this fact that the sporophyte, with its two complete sets of chromosomes, is really two beings in one, by designating it as the "2X generation." This contrasts it at once, in this important characteristic of chromosome number, with the gametophyte or "X generation."

Apparently, then, no actual *fusion* of the chromosomes is included in the nuclear union occurring at fertilization. The question at once arising is: Where in the life cycle is there any fusion, or intimate union of these inheritance-bearing units? The answer to this question was for some time generally believed to be offered by the phenomena associated with the process of "synapsis." Botanists had for some time noticed and figured the peculiar contraction of the chromatin of the spore mother-cell nucleus occurring just before the chromosomes for the reduction division are formed. Moore (1895) reaffirmed Strasburger's view that, even with the best preservation, the chromatin regularly assumes this condition at sporogenesis, and then only. Moore, therefore, declared this condition to be not an artifact, as many workers had held, but a natural process, which he named "synapsis." In spite of the insistence by an occasional worker that synapsis is an artifact, the impression of its constancy and peculiarity grew more general at the end of the last century. Then in 1901 Montgomery suggested that it is in this process that the long-delayed union of the paternal and maternal chromatin occurs. Montgomery's conception, that each of the double or bivalent chromosomes formed on emergence from synapsis is made up of a paternal and a maternal chromosome, which have in some way been paired up during the synaptic process, came to be rather generally accepted.

Recently, however, a number of workers have dissented vigorously from the view that synapsis is a constant, or a highly significant process. Thus Gregoire (1910), Gates (1911), and Lawson (1912) hold that it does not occur unfailingly at sporogenesis. Lawson says that so much of the separation of the chromatin from the nuclear wall as is not due to fixation is attributable to the more rapid growth of the nuclear wall than of the chromatin. Finally all three agree that such a process is not needed for the pairing of the chromosomes, since, as was observed by Strasburger (1905) and others, the chromosomes may regularly appear in pairs in the vegetative mitoses of the sporophyte. Moreover, studies of the vegetative nuclei of the sporophyte, especially by Gregoire and his students, show that their chromosomes are closely connected by adhesions, and by pseudopodium-like strands developed between the viscid chromosomes when the new reticulum is formed after each mitosis. Gates (1911), after reviewing recent work on this point, holds that the pairs seen in vegetative mitoses are of a paternal and a maternal chromosome each. He sees no adequate reason for thinking that the association of parental chromosomes at synapsis is any more intimate than that which occurs, as he says, "at or soon after fertilization." He evidently regards the connections between sporophytic chromosomes referred to above as affording ample opportunity for any interchange of material or "influences" between the chromosomes. Gates does not say just when the parental chromosomes are first paired up after fertilization nor give the evidence for this. He fails also to explain the fact, upon which practically all workers seem agreed, that the constituent chromosomes of the diploid pair are associated with each other in a more intimate way than are the chromosomes of any other mitosis in the life cycle.

VI.—ALTERNATION AND CHROMOSOME NUMBERS IN THE ALGÆ, 1896.

We have already seen that an attempt was made in the third quarter of last century to interpret the life histories of certain thallophytes, especially among the algæ, in terms of the alternating generations discovered by Hofmeister among the archegoniates. The basis of comparison was the occurrence of a sort of polyembryony at the germination of the sexually produced oospore in these algæ. There was much uncertainty, however, concerning the exact correspondence of phases in the two groups, and even as to whether the alternation was of the same sort in the two groups.

With the promulgation of Strasburger's view (1894) regarding the significance of the reduction of the chromosome number in the life cycle, botanists felt that they would now be able to distinguish the phases of a real alternation of generations wherever chromosomes could be counted. A number of workers therefore followed out cytologically the details of development and conjugation of the sexual cells, and the germination of the zygote in various algæ.

The work of Chmielewski (1890) on Spirogyra, and of Klebahn (1891) on desmids showed some indications of a reduction process at the germination of the zygote in these forms, though chromosomes could not be counted. Not till very recently was it demonstrated for one of these, Spirogyra, that the chromosome number is actually reduced at this time. Tröndle (1911) has counted chromosomes of Spirogyra and finds that there is a real reduction here, and that three of the first four nuclei formed in the zygote degenerate, the fourth remaining as the nucleus of the single embryonic plant formed.

In a study of the green alga Coleochæte, Allen (1905) showed that the chromosome reduction occurs with the beginning of germination of the zygote. Hence the group of zoospore-producing cells arising from the latter is not to be regarded as a sporophyte, as had often been maintained. Allen thus eliminated the only ancestral prototype of the bryophyte sporogonium that the antithetic alternationists had been able to discover among the green algæ.

The search among the brown algæ for parallels to the chromosome history of the cormophytes has been much more successful. The first case made out, that of Fucus, by Farmer and Williams (1896) and by Strasburger (1897) seemed, it is true, not very illuminating. They found the reduction occurring in the first divisions of what seemed clearly to be the egg- and sperm-producing organs, a point where it occurs in no other green plant. This case of Fucus, you will remember, is the one used by Scott (1896) to point a moral, when voicing the generally felt criticism of those botanists who proposed "making the number of chromosomes the criterion by which the two generations are to be distinguished." Scott says:

> I venture to think it premature to rush into inductive reasoning from imperfectly established premises. The case of Fucus in which the Fucus plant is shown to have the full number of chromosomes goes dead against the idea that the sexual generation (and who could call a Fucus plant anything but sexual) necessarily has the reduced number of chromosomes. This fact is indeed a rebuff to deductive morphology.

When, however, Strasburger (1906) and Yamanouchi (1909) followed out the logical trend of the chromosome evidence unreservedly, this life history of Fucus became more readily comparable with that of the cormophytes, and with those of certain brown and red algæ that had in the meantime been elucidated by Williams and Yamanouchi. From this point of view, elaborated most completely by Yamanouchi, the Fucus plant with its 2X number of chromosomes is a sporophyte, and the reproductive organs arising in its conceptacles are sporangia comparable with those of a seed plant. After the reduction, which occurs at the normal point, at sporogenesis, each of the four megaspores, without escaping, gives rise to a gametophyte of two fertile cells or eggs. Each of the four microspores in turn forms a gametophyte, or X generation, of but sixteen cells, each of which is fertile and forms a spermatozoid. It is interesting to note here the similarity which has been pointed out by Strasburger and by Chamberlain of the chromosome cycle of Fucus to that of animals. In the latter, from the plant cytologist's point of view, the sexual generation has become reduced to the four haploid nuclei formed at spermatogenesis and oogenesis, and the so-called ovary and spermary are really spore-producing organs of the 2X or asexual generation.

In the brown seaweed Dictyota the discovery of the chromosome cycle revealed, for the first time in any thallophyte, an alternation that seemed clearly comparable with that of the cormophytes in this respect. Williams (1904) was able to show that the morphologically similar, mature plants of *Dictyota dichotoma* differ not only in that some produce spores only and others male or female reproductive cells only, but also that the nuclei of the former have twice as many chromosomes as those of the sexual plants. He found also that the number of chromosomes is reduced at tetraspore formation and held that all this cytological evidence indicated the alternation of the sexual and the tetrasporic plants. The doubts of conservative botanists regarding the regular and necessary sequence of these haploid and diploid plants were dissipated when Hoyt (1910) raised fruiting tetrasporic plants from eggs, and mature sexual plants from tetraspores. Hoyt thus demonstrated by cultures, for the first time in any alga, the identity of this alternation with that of the cormophytes. Yamanouchi (1911 and 1913) has demonstrated, cytologically and in part by cultures, the occurrence of an exactly similar type of alternation in the brown algæ Cutleria and Zanardinia, the life cycle of Cutleria seeming peculiarly like that of the cormophytes because the two generations differ not only in chromatin content, but also in structure.

In the red seaweeds also the use of cytological methods and the determination of chromosome numbers has given a series of very suggestive, though not as yet easily interpreted, results. Oltmanns (1898) showed that the nucleus of the carpospore is a direct descendant of the diploid oöspore nucleus. Wolfe (1904) decided that in Nemalion, a species that does not form tetraspores, the reduction occurs at the budding out of the carpospores from the mass of cells arising by division of the fertilized egg. He therefore follows Oltmanns in regarding the diploid cell mass mentioned as the sporophyte of this species. In a series of red algæ, which have a tetrasporic phase in the life cycle, Yamanouchi (1906), Lewis (1909), and Svedelius (1911) have found cytological evidence of an alternation of two generations similar in character to that first seen in Dictyota. Lewis (1912) later proved conclusively by the use of cultures that the haploid sexual plants arise from tetraspores only, while the diploid fertilized egg gives rise, through the carpospores formed from it, to tetrasporic plants only.

In the interpretation of the phenomena seen in these red algæ Yamanouchi regards the tetrasporic plant as the more primitive phase of the 2X generation, and carpospore-formation as a sort of secondarily developed polyembryony for multiplying the progeny from each fertilization. Lewis, on the contrary, holds the view that the tetrasporic plant is, in origin, an early, self-propagative phase of the primitive, haploid, sexual generation. Further he suggests that, in accordance with a general tendency evident in many sexual plants, the process of reduction has here been postponed and pushed forward from the time of carpospore-formation, where it still occurs in the primitive form Nemalion, into this originally haploid tetrasporic plant.

Though no generally accepted interpretation has yet appeared of the somewhat varying chromosome cycles that have now been elucidated in green, brown, and red algæ, yet the mass of facts thus far obtained presents an impressive picture of the essential identity of reproductive processes in these plants with those found in the cormophytes. Perhaps the most interesting point noted in making such a comparison is the fact that the type of life cycle among algæ that corresponds most closely with that of a higher plant, such as an archegoniate, is the type found in several genera of the brown algæ. The fact may be recalled here also that it was to the gametangia of this group that Davis (1903) finally turned in his search for a prototype of sexual reproductive organs of the bryophytes.

VII.—SEXUALITY, CHROMOSOME HISTORY AND ALTERNATION IN THE FUNGI, 1820.

In this group of parasitic or saprophytic thallophytes we shall find as great a variety in the type of reproductive process as in their mode of nutrition at the expense of the hosts beset by them. At the beginning of last century fungi were commonly supposed to arise spontaneously "out of the superfluous moisture of the earth and rotten wood."

Observations had been made long before this, it is true, sufficient to render improbable the then common belief in the spontaneous generation of the fungi. Thus Micheli (1729) had raised a fungus mycelium from spores. Ehrenberg (1820) did the same and also saw the conjugation of Sporodinia. Du Trochet (1834) proved that the mushroom arises from threads of the mycelium in the soil.

The spontaneous generation of even the simplest of these parasitic or saprophytic thallophytes—the bacteria—had been denied by Leeuwenhoek at the end of the seventeenth century. In one of his numerous letters to the Royal Society he denies the spontaneous origin of the animalculæ or bacteria which he found in the mouth. These he found present even in the mouths of ladies who cleaned their teeth carefully. He insists that these organisms are like those he obtained from pools of water, and then goes on to say, in a paragraph that reads like a modern health commissioner's report:

> Now, when people wash their beer mugs and drinking cups in the water from ponds and streams, who can tell how many of these animalculæ may stick to the sides of the glass and thus get into the mouth.

The hazy or bizarre beliefs concerning the occurrence and the mode of reproduction in the fungi, current at the middle of last century, were dispelled by the studies of a group of able investigators early in the second half of the century. First came the splendid work of the brothers Tulasne (1847–1854) on the smuts and rusts, and their discovery of the oögonium of Peronospora. Pringsheim, in 1857, studied the sequence in development of the zoosporangia and oögonia of the water molds. Then came the researches of that master mycologist, Anton De Bary, on the reproductive structures of Peronospora (1861), of Pyronema and Sphærotheca (1863), and on the life histories of the rusts, 1853 and 1865. The results of his own work and that of his students Woronin and Janczewski convinced De Bary that, in the Ascomycetes, as well as in the phycomycetous Peronosporas, the contents of an oögonium is fertilized by the escape into it of the living contents of the antheridial tube that grows beside it.

In the seventies and eighties a vast number of detailed observations concerning reproductive processes in the fungi were accumulated by many observers, led especially be De Bary's student, Brefeld. One outcome of this work which concerns our particular problem was the insistent, though unconvincing, denial by Brefeld of the sexuality of the Ascomycetes.

In the last decade of the nineteenth century, with the application of new methods of fixing, sectioning, and staining, a new era opened in the study of sexuality in the fungi, an era in which American workers have played a prominent part from the beginning.

As early as 1886 Rosenvinge had succeeded in staining the many nuclei of the mycelial cells of toadstools; also the primary basidium nucleus and the four-spore nuclei arising from this.

Humphrey (1892) and Hartog (1895) followed the history of the nuclei in the antheridium and oögonium of Saprolegnia by the use of stained sections, and concluded, as De Bary had done, that there is no fertilization in these forms. Not until the work of Trow (1904) and Claussen (1908) was it proven that the antheridium of these water molds, at least in some species, may be functional, and not always vestigial, as De Bary (1881) and Humphrey had thought.

The earliest cytological work on the Ascomycetes, after the detection of their nuclei by Schmitz, was that of Dangeard (1894). He described and figured a fusion of two nuclei in the ascus of Exoascus, of Peziza, of the truffle, and others. The source of the two fusing nuclei Dangeard did not trace back farther than the subterminal cell of a hooked hypha, from which the ascus arises in Peziza and others. The ascus, with its fusion nucleus, he regarded as an oöspore.

In 1895 there was announced from Strasburger's famous laboratory at Bonn a discovery which seemed at one stroke to settle the dispute between De Bary and Brefeld, and to definitely demonstrate the occurrence of a sexual nuclear fusion in the sexual organs seen by De Bary. In that year Harper showed that out of the opened antheridial tube of the hop mildew, Sphærotheca, a male nucleus passes into the oögonium and fuses with its nucleus. The whole behavior of antheridium and oögonium and their contents had every aspect of a real sexual process, as De Bary had asserted in 1863. What made Harper's discovery still more significant was the determination of the fate of the fusion nucleus in relation to the nuclei of the ascus and spores. Harper found that one of the row of five or six cells resulting from the division of the fertilized oögonium has two nuclei. These two descendants of the diploid nucleus, formed at fertilization, afterwards fuse, and the cell containing them swells to form the single ascus of this species. This, presumably tetraploid, fusion nucleus of the ascus then grows and divides three times to give the eight spore nuclei. In the following year or two Harper (1896–97) demonstrated a sexual fusion of the same type at the initiation of the fruits of another mildew Erysibe, and of the saucer fungus Ascobolus. The numerous asci of these forms all, arise from binucleate branches of the binucleate, subterminal cell of the fertilized oögonium. Each ascus is at first binucleate, but later, as had been seen by Dangeard (1894), the two fuse and then by division the eight spore nuclei are formed as in Sphærotheca.

In the course of the following decade Harper reported the occurrence of two nuclear fusions, like those of Sphærotheca, and at the same points in the life cycle, in the mildews Erysibe (1896) and Phyllactinia (1905), and in the saucer fungus Pyronema (1900). Moreover, he found in Phyllactinia a synapsis and evidences of a double reduction of the chromosome number in the divisions of the presumably tetraploid, fusion nucleus of the ascus. Pyronema proved interesting also in having multinucleate gametes, such as were at this time being studied by Stevens in the white rust Albugo. Harper believed that many pairs of male and female nuclei fuse in the oögonium of Pyronema.

As the outcome of this whole series of studies by Harper it seemed clear that there is in many Ascomycetes an alternation of a haploid generation, the vegetative mycelium and the sterile hyphæ of the fruit, with a diploid generation, the fertilized oögonium and the ascus-forming hyphæ arising from it. The second fusion, in the ascus, was regarded as a nutritive phenomenon to provide a nucleus adequate in size for the organization of the relatively huge ascus.

At the opening of the century the observations of a number of workers on the simpler Ascomycetes, e. g., those of Juel (1902) and Barker (1902), seemed to establish the occurrence of a nuclear fusion in the oögonium in these forms also. This, with Harper's work, made it seem probable that this fusion is a frequent phenomenon throughout all the Ascomycetes.

The researches of certain other cytological workers, however, convinced them that no fusion of nuclei really occurs in the oögonium of the Ascomycetes which they studied. Thus, Dangeard (1897 and 1907), working on Sphærotheca and Erysibe, found no fusion except that in the ascus. Claussen (1907) and Brown (1909) could find no other in the varieties of Pyronema studied by them. Both workers find paired nuclei associated in the ascogenous hyphæ and finally in the young ascus. Claussen therefore regards the fusion in the young ascus as a union of descendants of the sexual nuclei that were brought together in the oögonium but did not fuse there. In other words, he thinks it a real sexual fusion which has been deferred. Brown, on the other hand, says that in his plant no antheridial nuclei are concerned, since the antheridium never reaches the oögonium. He therefore regards the fusion of pairs of nuclei, derived from the oögonium, which occurs in the ascus, as one that serves as a substitute for the sexual fusion that primitively occurred in the oögonium. Brown's view is supported further by his work on Lachnea (1911), and by Faull's recent work (1912) on certain Laboulbenias.

If this view of Brown's be accepted it implies that the original diploid condition of the cells of the sporophyte has been altogether eliminated, except for the brief uninucleate stage of the ascus. In spite of this, however, the whole structure and development of the original 2X generation, from fertilized oögonium to mature fruit and ascus, has been retained. This same normal type of vegetative structure, in spite of an abnormal chromosome number, has been demonstrated in gametophyte and sporophyte of aposporous and apogamous mosses and ferns. It is implied also in Lewis's suggestion that, in the red seaweeds, the reduction has been postponed from its original location at carpospore-formation over into the primitively haploid tetrasporic phase of the next generation.

Still other recent work on the Ascomycetes, however, supports Harper's view that a double fusion frequently occurs in these fungi. Thus Blackman and Fraser (1906), Fraser (1907–8), and Fraser and Brooks (1909) find evidence of several steps in the loss of function of the antheridia in the different species of the cup fungi Lachnea and Humaria. In those cases where no antheridial nuclei are discharged into the oögonium, nuclei of this organ itself are believed, by these workers, to fuse in pairs within it. The later fusion in the ascus, which they find in common with all workers, they regard as a nutritive phenomenon.

Until toward the end of last century the Basidiomycetes were generally assumed not to be sexual. At least no sexual organs had been described for them, with the exception of the spermagonia and æcidia of the plant rusts. These had been called male and female organs, respectively, by Meyen, before the middle of the century. The very first nuclear studies of the rusts and toadstools, however, revealed the occurrence of a nuclear fusion, and at another point in the life history indications of the complementary process, a reduction, were discovered.

In the case of the rusts Rosen (1892) saw two nuclei in the æcidiospore of certain species. Dangeard and Sapin-Trouffy (1893) reported the occurrence of a nuclear fusion in the teleutospore. Sapin-Trouffy (1896) found that the cells of the æcidium-bearing mycelium are uninucleate up to the very base of the chain of æcidiospores. Maire (1900) first stated clearly the whole nuclear cycle in rusts: Beginning with the binucleate æcidiospore there follows, e. g., in the wheat rust, the uredo or rust stage, which has a binucleate mycelium and forms binucleate uredospores for several generations. The two nuclei of the young teleutospore, finally formed on this mycelium, fuse as the spore matures. The two divisions of this fusion nucleus in the promycelium give rise to the four nuclei of the four sporidia which germinate to the uninucleate cluster cup mycelium on the barberry. Maire saw in this life history a real alternation of generations, the gametophyte or X generation beginning with the sporidium, the sporophyte or 2X generation, with the mother cell of the æcidiospore chain.

Blackman (1904) and Christman (1905) discovered the origin of the binucleate condition of this mother cell in species of Phragmidium. It there arises by the migration of a nucleus from one cell into another, or by the fusion of the cytoplasm of two cells to form the mother cell of the spore chain. The two nuclei thus brought together divide simultaneously or conjugately, each contributing a nucleus to the first and to each succeeding spore. This conjugate division of the paired nuclei and their descendants was shown to occur all through the uredo generation up to the formation of the young teleutospore. In the interpretation of their discoveries Blackman and Christman differ more widely than in the facts reported. The former supports the surmise of Meyen, and believes the basal cells of the spore chain are oogonia which were primitively fertilized by the now functionless spermatia, or pycnospores, that are produced in separate organs on the barberry leaf. Christman, on the contrary, regards the fusing cells at the base of the æcidium as the primitive, undifferentiated sexual organs of these fungi. He holds that male and female organs have never become differentiated in this group, and thinks that the spermatia are, or were, propagative cells of the X generation.

The observations of many workers on the smuts and on the toadstools have shown the frequent occurrence in them of an association of nuclei and the final fusion of two nuclei in the chlamydospore or the basidium. The time and mode of association of the fusing nuclei, or of their progenitors, are very different in different forms. The fusion, and what appear to be the reduction divisions are, however, constant in location in each species, and are always closely associated. Thus, the nuclear fusion in the smuts often occurs in the chlamydospore, according to Dangeard (1893) and Rawitscher (1912), and reduction evidently follows immediately in the next developmental phase, when this spore germinates to form the sporidia. In the toadstools, according to Wager (1893), Dangeard (1894), Harper (1902), Nichols (1904), and Levine (1913), the fusion of nuclei occurs in the basidium, and the reduction at the very next division of this fusion product, when the four spore nuclei are formed.

The striking uniformity with which the apparent reduction occurs in all Basidiomycetes, at the time of formation of the sporidia or basidiospores, affords good evidence that this type of spore formation is a long-established one, common to the whole group. It thus supports Brefeld's view that the promycelium of the smuts and rusts is homologous with the basidium of the higher forms. That the point in the life cycle where the associated nuclei finally fuse is the point at which it occurred in the earliest Basidiomycetes is not so clear. The modes of bringing about the first association of the paired nuclei are so varied that it is difficult to detect any clearly ancestral type among them all. The structures concerned with this process in the æcidium-forming rusts certainly seem most readily comparable with the reproductive organs of other thallophytes. It seems probable that the occurrence of fusion at the same point in all forms is due to its being postponed in all forms as long as it could be, without being pushed over into another phase of the life cycle.

It would be instructive to spend another half hour, as we can not do here, in considering those peculiar short cuts in reproduction known as apogamy and apospory. These phenomena are so patently secondary and so relatively infrequent that they can not be looked to for evidence of fundamental importance concerning the history or the significance of the essential sexual process itself. Their study has, however, served to correct certain false assumptions concerning the relation between the difference in chromosome number and the difference in structure of the two generations. For example, the apogamous production, by *Nephrodium molle*, of a normal fern sporophyte with the X number of chromosomes demonstrates as no other kind of evidence could that De Vries was right in regarding the normal sporophyte as really two beings in one. Incidentally too, such phenomena suggest how comparatively unimportant it is for the structure of the plant, in what manner, and at what point in the life history the association of the 2X number of chromosomes is brought about.

CONCLUSION.

In our rapid glance at the progress made in the study of this problem during 20 centuries we have seen how for 18 centuries men attempted to solve the problem by recourse to philosophical reasoning, without the aid of detailed observation or experiment. Then, in less than 2 centuries, by the use of these means, Camerarius proved that pollination is a necessary condition of seed formation; Koelreuter demonstrated that characters from both parents appear in hybrid offspring; Amici, Pringsheim, Schmitz, and Strasburger showed how the mingling of parental qualities is made possible by the approximation and mingling of parental protoplasms and nuclei.

The sexuality which was first suspected and first experimentally proven in the seed plants has now been demonstrated in all groups of plants save the bacteria and their allies. The primary feature of the process, the union of two parental nuclei, is the same in all. The method of bringing together the two nuclei varies widely, this variation sometimes involving even the complete disappearance of externally recognizable sexual organs. During the evolution of plants old methods of accomplishing the approximation of the nuclei have been discarded, and new methods have arisen. In the latter case a fusion of nuclei of closer kinship has often been substituted for the primitive one of more distantly related nuclei. This seems evidently the case, for example, in the apogamous Ascomycetes; perhaps also in the Basidiomycetes, and surely so in the cases of nuclear fusion in the prothallia and in the sporangia of apogamous ferns.

In the process of fertilization, as we understand it at present, there are brought together two distinct sets of chromosomes, which in the nuclear divisions of the sporophyte, or 2X generation, are often found associated in pairs. The exact manner in which these chromosomes become paired, and the possibility of their attaining any more intimate association, either in the resting reticulum or in synapsis, are not yet definitely determined. If, as is indicated by Mendelian phenomena, and as demonstrated cytologically to the satisfaction of many workers, there is no loss of identity of the chromosomes in the sporophyte, then there is no very *significant* fusion at any point in the life cycle in consequence of the sexual process. Members of the two sets of chromosomes may be interchanged or shuffled, probably at synapsis, and thus new sets or combinations be formed in the haploid nuclei at reduction. These new combinations, however, are still made up of the same discrete individual chromosomes.

The essence of the sexual process then, as far as yet morphologically demonstrated, consists not of a real fusion, but merely of a temporary association, followed by a reassortment at sporogenesis of those ultimate, inheritance-bearing units—the chromosomes.

PROBLEMS AND PROGRESS IN PLANT PATHOLOGY.[1]

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I.—INTRODUCTION.

It may be assumed, I trust, that I am doing the expected thing in choosing the topic of this address from my own field, phytopathology. If, however, justification is asked, the answer is clear. Plant pathology is simply a phase of botany. Practically all progress to date in its scientific development is owing to botanists. The rapid increase in numbers of those engaged upon work in this branch of botanical science has, however, naturally crystallized certain tendencies to segregation, giving us our independent Phytopathological Society with its separate program and its own journal. While this segregation is, in my judgment, the natural and wholesome result of progress, it creates problems and embodies danger to both parties. To the parent group, these lie in the loss of close association which it has heretofore had with some of its virile younger members; to the younger branch, there is the even more serious danger in passing from the critical and standardizing influence of the general Botanical Society, dominated by maturer minds and broader ideals.

If we accept as true the statement of one year ago by Dr. Farlow[2] that America is to-day surpassing other nations in the study and applications of plant pathology, perhaps the first phase of biological science where this can be asserted, all will agree that much credit for this is due to the fact that our methods, ideals, and leadership have come directly from botanical circles. Now that these relations are becoming less intimate, the responsibility rests upon both parties to see that by conscious effort we keep in closest touch, that the dangers of mutual loss from segregation be minimized to the utmost.

I have chosen the combination title "Problems and Progress," because of the necessary relationship of these two ideas. There may, indeed, be difference of opinion as to the relative stage of scientific progress in plant pathology, as compared with other branches of botany. There must, however, be general agreement as to the relatively great increase in activity in this field in the last two decades. Activity is the gauge of life, and fullness of life should be the best criterion of progress. But we all recognize that whether or not activity or life in any scientific field does measure progress depends upon whether or not action is directed toward the solution of fundamental problems.

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[1] Address of the retiring president of the Botanical Society of America, read at the Atlanta meeting, Dec. 31, 1913. Reprinted by permission from the American Journal of Botany, March, 1914.

[2] Farlow, W. G. The change from the old to the new botany in the United States. Science, N. S. 37: 79. 1913.

Let us with this in mind review the progress in phytopathology, trying to define and delimit some of the chief problems as they have successively arisen and to decide in how far they have been solved.

II.—THE PROBLEM OF PARASITISM.

Practical-minded men have faced the problems of disease in plants since plant culture began and those more scientifically minded have, of course, speculated or investigated in the matter. But it will profit us little to go back much more than a century for inquiry into either their definition of the problems or their progress in the solution. When Count Re, of Italy (1807),[1] following the lead of the Tyrolese von Zallinger (1773), attempted an account of what was known about plant diseases, practical or scientific, the result was largely barren because he had no conception of the meaning of parasitism. Little was known about the fungi and less about their host relations. Schweinitz, Persoon, and Fries soon laid the secure foundations for mycological nomenclature and species descriptions, secure because based on keen observations and critical comparisons. But they had no concern with plant pathology, and their contemporaries who had, were star-gazing with the nature philosophers. Thus Count Re's work remained nearly half a century after it was published as a standard writing in plant pathology.[2]

It required the plague of the potato disease and the example of the Irish famine finally to focus attention upon the fundamental problem—the relation of the mildew to the sick potato plant, of the smut and rust fungi to the infected grain—the problem of parasitism. True, they had been phrasing the term parasite much as we do, but so long as most held that the so-called parasitic fungus originated through the transformation of the sap or the degeneration of the diseased host tissues there could be no real progress in plant pathology whether scientific or practical. To De Bary's master mind we owe the clear recognition of the parasitic relations of fungus and host plant,[3] and from his demonstration of this we date further progress.

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[1] Re, Fillipo. Saggio teorico pratico sulle malattie delle piante. Veneziae, 1807. An English translation was published in Gardiner's Chronicle, 1849, p. 228.

[2] The editor of Gardiner's Chronicle (1849, p. 211) prefaces the translation of Re's work with the statement that "it is the best work within our knowledge" upon this subject.

[3] De Bary, A. Untersuchungen über die Brandpilze und die durch sie verursachten Krankheiten der Pflanzen mit Rücksicht auf das Getreide und andere Nutzpflanzen. 1853.

But although De Bary's work has settled for all time that the parasite is an independent plant entering the host from without and feeding upon it to its destruction, we must not forget that the more fundamental problems of parasitism remain with us. In biology, the definition is always dangerous, and the more complete and finished the more the danger. De Bary's classification of all fungi as parasites and saprophytes, obligate and facultative, is so complete and satisfying that it is constantly misleading. De Bary thought as the mycologist with attention focused upon the fungus. The first concern of the pathologist must ever be with the host plant, and chiefly with the host plant under conditions of culture. He must constantly be alert to the fact that parasitism is not a fixed but a fluctuating relation, dependent as to its occurrence and degree upon a complex of conditions, and these involving the reactions of not one but two widely different organisms. Although the fact of parasitism was settled and the modern science of plant pathology securely based upon it, there has been no time since when phytopathologists realized as clearly as to-day the importance of the problems yet to be solved in this field. We have scarcely begun the study of the intimate relations of parasite and host, the conditions and results of parasitism.

III. THE LIFE-HISTORY PROBLEMS.

The fact of parasitism accepted, the problem of the life-history of the parasite at once presented itself to these early students. Kühn's work on grain infection by smut (1858) and De Bary's upon the life histories of the Peronosporales (1863) with proof of heteroecism of the rusts (1864–65) set the pace. In the retiring address of my predecessor,[1] we learned how Farlow brought to this country the coals which have kindled the fires of our best American research in mycological pathology.

It should remain the first concern of plant pathologists that this work be continued. Discoveries as to life histories of parasites are, in the long run, of more practical importance as fundamental for disease control than demonstrations with spray mixtures. The latter are usually transient contributions, the former permanent. It is, therefore, of good promise that the two life-history problems which first engaged De Bary's efforts, those of the grain rust and the potato fungus, are to-day held more open and are receiving more earnest attention than when De Bary died. It is well that the problem of the overwintering of the apple scab is no sooner settled by one investigator for one locality than it is opened by another, working in a different environment. Life-history problems have so many variations and complexities that they must ever remain with us, and progress in their fuller solution will continue as one index to general progress in plant pathology.

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[1] Farlow, W. G., loc. cit.

It is fortunate that they are so well suited for thesis problems of graduate students, and we may hope that the traditions established in the laboratories of Farlow and Atkinson may be perpetuated as well in other institutions.

IV.—THE CULTURE PROBLEMS.

While De Bary in Germany was laying the foundation of mycological morphology, Pasteur in France was doing a correspondingly important work on the side of physiology, dealing with the fundamentals of fermentation and nutrition. Following his initial efforts, the problem of the pure culture with yeasts and bacteria was promptly defined and solved. Bacteriology not only came quickly into existence, but soon became the most exact science of the biological group, owing to the fact that in such pure cultures environmental conditions can be controlled to a degree unattainable with the higher organisms.

Brefeld's success in culturing the smuts directed attention to this new method in studying the fungous parasites. Although the methods were adapted from those of the bacteriologists their uses with fungi are somwehat different. With these it is not only the gain from exact handling in differentiating mixed infections and inoculating from pure cultures, but also in completing life-history investigations. With the imperfect fungi and Pyrenomycetes the method is especially applicable and the recent work on Glomerella by Shear[1] and Edgerton[2] illustrates well its advantages. To this method *Phytophthora infestans* has at last yielded the clue to its complete life history,[3] although here as always the developments in the culture tube need to be checked by comparison with those in nature.

For culturing the plant pathogens the value of the solid over liquid media and of vegetable over animal extracts becomes increasingly evident with experience. Thus the merits of Clinton's oat agar which gave such important results with Phytophthora have again been shown by the development upon this medium in our laboratory of perithecia of the apple scab fungus in greater abundance and vigor than ever observed in nature.[4] It should be assumed that for all such fungi which develop part of their fruiting stages saprophytically we may perfect culture media and methods which will not only stimulate but may improve on those of nature.

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[1] Shear, C. L. and Wood, A. K., Studies of fungous parasites belonging to the genus Glomerella. U. S. Dept. Agr., Bu. Pl. Ind. Bul. 252. 1913.

[2] Edgerton, C. W., Plus and minus strains in an Ascomycete. Science, N. S. 35: 151. 1912; also paper read at this Atlanta meeting.

[3] See Jones, L. R. and Giddings, N. J. Studies of the potato fungus. Science, N. S. 39: 271. 1909. See also ibid. 30: 813. 1909; 31: 752. 1910. Clinton, G. P., Oospores of potato blight. Science, N. S. 33: 744. 1911; Conn. Agr. Exp. Sta. Rept. 1909–10: 753. Jones, Giddings and Lutman, Investigations of the potato fungus. U. S. Department Agriculture, Bu. Pl. Ind. Bul. 245. 1912. Pethybridge, G. H., On pure cultures of Phytophthora infestans De Bary and the development of oospores. Sci. Proc. Royal Dublin Soc. 13: 556. 1913.

[4] See abstract of paper by F. R. Jones: "Perithecia in cultures of Venturia inaequalis." Phytopathology 4: 52. 1914.

And even the so-called obligate parasites deserve attention, for we are not restricted to artificial or dead media in pure culture work. The living sterile tissues of the proper host may be secured for many parasites providing only the need is sufficient to justify the painstaking. This of course, is easy with many interior tissues of fleshy parts, while for various other plants the seedlings may be grown from sterile seeds. It would seem that the problem of whether or not *Plasmodiophora brassicae* is the sole cause of club root of crucifers, or whether association is necessary with bacterial or other organisms, as has been suggested,[1] is a challenge to such increased skill in culture technique.

Finally, there is culturing upon the living host. Although this was the earliest method in vogue, and has yielded such gains especially in the hands of Arthur and others with rusts, yet the general applicability and importance of this practice in plant pathological investigations has not been fully realized. It is only thus that we can learn with exactness of related varietal or species susceptibility of hosts on the one hand and of the occurrence of biological forms among parasites on the other—both things of paramount importance in plant pathology, scientific and economic. Success in such work is conditioned upon our ability to control and interpret environmental conditions. When the superiority of the greenhouse for such studies is more fully realized, we shall here work out the most of our fundamental problems, with the field plat as the place more important for verification than for investigation.

V.—BACTERIA IN RELATION TO PLANT DISEASE.

The problems of bacteria in relation to plant disease naturally followed the advent of the pure-culture method. While, from the American standpoint, this is the most important chapter in the development of modern plant pathology, it is at the same time, to us, the most familiar. The universally acknowledged world supremacy rests here, thanks to the high ideals and energetic—at times militant—leadership of him who two years ago was the honored president of this society. I may only outline certain things in order to warn of dangers or suggest other problems.

Since the work of Burrill, over 40 years ago, no American worker has doubted the occurrence of bacterial diseases of plants. That Europeans were skeptical for a time was the natural consequence of too great reliance upon tradition and too great respect for authority. And as we grow older in the work in America we must realize that the traditions will soon be ours and that the paralyzing hand of authority will rest more heavily upon us. While in general we must follow its lead, and the "progressive" who breaks from the ranks must do so at his peril, let us keep alive to the need of progressiveness, and be patient with the man who challenges a traditional idea. Of course, every American recognizes fire blight of pear as the "classic" among bacterial diseases. But there may be blight which is not the bacterial fire blight. It is a wholesome thing, therefore, to have a challenge issued. It has been too easy, at least in horticultural circles of the west, to attribute all types of blighting of pear and apple trees to *Bacillus amylovorus*. One of the most reassuring things about the chestnut blight situation has been the fact that from the outset there have been those who must be converted. I have for years been convinced that American pathologists have relied too implicitly on authority in attributing all potato scab to one organism. Now that our so-called "*Oospora scabies*" seems to be of a bacterial nature[1] and the powdery scab of Europe is threatening if not invading our territory, we may hope for a revival of first-hand investigations. And may we not be in danger of generalizing too broadly with reference to galls? The brilliancy and thoroughness of the recent work[2] upon crown gall will almost inevitably encourage this in spite of the guarded and conservative statements made by the authors themselves.

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[1] Pinoy, Rôle des bactéries dans le developpement du Plasmodiophora brassicae. Compt. Rend. Soc. Biol. 58: 1010. 1905.

The natural consequence of the general acceptance of the fact of bacterial diseases of plants, coupled with the lack of adequate training in bacteriological technique, led many in the early days to attribute numerous diseases to bacteria upon incomplete evidence. Nor was this confined to America. European literature, especially the French, has many such announcements. We need not criticise these too severely as to the past. It was natural and inevitable. But we are increasingly blameworthy if we continue either to publish carelessly or to accept the announcements of others without critical review. With the appearance of Smith's monographic work on Bacteria in Relation to Plant Diseases, any American, at least, who describes a "new" bacterial disease of plants upon inadequate data should realize that he is committing an offense against the American profession.

This is not to imply that there are not plenty of bacterial diseases of plants yet to be discovered, nor to discourage the search for these. It is rather to emphasize that there are other problems better worth while than the search for "new" diseases of minor economic importance. The simplicity of the bacteria in their relations to host and in the way they lend themselves to culture and infection stimulate the hope that through persistent intensive study of bacterial diseases we shall gain the clearer insight into those intimate relations of parasite and host which are fundamental to the science of plant pathology.

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[1] Cunningham, G. C. The relationship of Oospora scabies to the higher bacteria. Phytopathology 2: 97. 1912.

[2] Smith, E. F. Crown gall of plants. Phytopathology 1: 7. 1911. Smith, Brown, and McCulloch. The structure and development of crown gall: A plant cancer. U. S. Dept. Agric., Bur. Pl. Ind., Bull. 255, 1912.

VI.—THE RELATIONS OF PARASITE TO HOST AND ENVIRONMENT.

Although parasitology in relation to plant pathology dates from but little later than in animal pathology, and the relations involved would seem simpler than with the animal parasite, yet the fact remains that we are far behind the animal pathologists in understanding these relations. Some of the reasons for this are evident. The preeminent value of human life among the animals has focused attention upon human pathology. Even where attention has been given to the pathology of the lower animals, the students have as a rule approached the subject from the viewpoint of human pathology, and have been eager to apply to this any suggestions from comparative work on the lower forms. The result has been intensity and concentration of research upon the diseases of this one organism, man.

In plant pathology the natural tendency has been exactly the opposite. From the beginning the phytopathologist has included in his range of interests all the diseases of all plants known to him. The numbers of disease-inducing parasites is so enormous that it has consumed his professional energies simply to catalogue them. Concentration when attempted has been secured by narrowing one's interests within the parasitic group rather than within the host group.

I believe that we need to have, far more than heretofore, specialization by hosts in our phytopathological studies. Whether one is to probe deeper into problems of relations of environment to parasitism or into matters of predisposition and variations, either with host as to susceptibility or parasite as to its biological forms, attention should be focused long and intensively upon the one host. Experience has convinced me that one can not understand the diseases of a cultivated plant like the potato, for example, except as he understands them in relation not only to the normal physiology and morphology of the plant, but in relation to its history and its variations under culture. Progress requires that we have specialists on types of host plant as well as of parasite.

And passing to the cellular relations of host and parasite, how little we know! The very simplicity of the plant's organization makes the pathological reactions harder to investigate than with the animal. In the plant the unit in the more fundamental pathological relations is not the organism but the cell, an object so minute as to make the study of the chemical interrelations highly difficult. We recognize the cell membrane as the first barrier to be overcome by the invader and we believe the cytolytic enzyme the first weapon in the attack. Yet, save with certain soft rot diseases, we know little that is definite about these enzymes in their action. We see evidence of other disturbing effects of parasite upon host cells, even in advance of actual invasion. Sometimes these are inhibitory or fatal, sometimes stimulating. But we have scarcely sufficient basis for a suggestion as to the nature of the agents involved. Such problems call for the combined skill of pathologist, physiologist, cytologist, and chemist.

The variation in the occurrence of disease with environment is one of the commonest observations and a thing of the greatest practical moment. Yet how little progress we have made in understanding the factors. Climate and soil both are composites of many variables, which in turn may react on either host or parasite. Why is it that Rhizoctonia diseases and Blattrollkrankheit of the potato claim so much attention in certain sections of the United States while in others pathologists are skeptical as to their existence? Why is it that the bacterial black leg of the potato develops so much worse in the South than in the North? Why is it that with the melon the Fusarium wilt is the scourge of the one section and the bacterial wilt of another? Why is it that the yellows disease of cabbage exterminates the crop under certain conditions and is of minor importance under others?

It would seem that here are problems to challenge the attention of every pathologist. Yet if one turns to them he is balked at the outset. We have inadequate data as yet regarding the occurrence and distribution of even the commonest economic diseases in the United States. Let us unite in urging that in the reorganization of the work now in progress in the Bureau of Plant Industry the entire attention of at least one expert pathologist be given to collecting and analyzing such data, while all local pathologists pledge the undertaking continued support and cooperation. Coordinate with this, the local student of the special disease may make painstaking studies in field, greenhouse, and culture chamber, and in time delimit the effects of moisture, temperature, soil reaction, and like factors upon each parasite and host.

The evidence is accumulating that the variations in relations between parasite and host which give us specialized races of parasites on one hand, and on the other, gradations in disease resistance of host are of the greatest importance, whether scientific or practical. But we can as yet record little that helps us adequately to define the factors in the problems, much less to solve them.

As suggested before, these problems are at bottom physiological and of the most complex kind. The pathology of the past has been the work of the mycologist and the bacteriologist. That of the future must be increasingly dependent upon the physiologist; for what is pathology at bottom but abnormal physiology? Realizing how slow is progress upon the really fundamental problems in normal physiology and what dearth there is of workers adequately trained to grapple with them, we must be patient with ourselves, and beg the patience of others, when dealing thus with the abnormal. Perhaps our greatest hopes lie in the assurance that from now on increasing attention must and will be given to the training in physiology of those who are coming into the profession of plant pathology.

VII.—THE NONPARASITIC DISEASE.

If the early workers in plant pathology erred in failing to recognize the importance of parasites as causal agents, the recent ones have gone to the other extreme.

The mycologist and the bacteriologist naturally bring to our attention even the minor parasitic maladies; the physiologist has as yet rarely come to our aid. It is only as one undertakes the comprehensive study of the maladies of a particular host that he realizes how few of the nonparasitic diseases have been listed.

Perhaps the peach, the tobacco, and the potato are the only plants where the energies have been duly distributed between the investigations of parasitic and nonparasitic diseases. If anyone doubts that in these nonparasitic maladies we are dealing with specific diseases having clearly defined symptoms which follow a regular course, let him grow China asters for a series of years in his garden and trace the course of aster yellows.[1] Here we have a malady as clearly characterized as a fungous rust or wilt disease; unknown, I believe, in Eurpoe, but widespread in America, variable with season and locality, yet its etiology and pathology are entirely problematical.

But these are not problems to be undertaken lightly. Considering their inherent difficulties, we may be thankful that such critical and persistent work has been given to certain types already, notably to peach yellows by Smith and to the mosaic disease of tobacco by Mayer, Beijerinck, Woods, and others. It is encouraging to see that earnest attention is being given to certain apple maladies in different sections, especially the so-called "brown spot" or "bitter pit" in South Africa and Australia.[2]

Our encouragement will be greater, however, when we see the clear recognition of the fact that training in parasitology has only indirect value when it comes to such problems. The most evident need if we are to advance in the fundamentals of our research in this field of plant pathology is the reinforcement of our ranks with young men equipped with a high degree of special training in plant physiology grounded in organic chemistry, and ready to dedicate their services long and patiently to these physiological researches.

VIII.—THE PROBLEMS OF DISEASE CONTROL.

Now, you are expecting the statistics showing how many millions America is adding to her income by modern methods in disease control; but you have heard them often, so I need not repeat them; and they have much of truth in them. The Yankee is practical, and the Yankee mind dominates everywhere in America. Instead of boasting, we rather owe ourselves this explanation—shall we say apology?—when we point to the relative proportion of the space in American plant pathological publications given to the consideration of the spray pump and the disinfecting solution. How could it be otherwise? The millions spent by patent medicine advertisers have implanted firmly in the American mind the idea that each animal disease is a specific thing and for it there exists a specific remedy. It was, therefore, most lucky that when the professional "plant doctor" was introduced to the American rural constituency by the State experiment stations and National Department of Agriculture he could step forward with Bordeaux mixture in one hand and formaldehyde in the other, two specifics which could at once be used and misused in a most amazing variety of cases without serious danger of loss of life or reputation. And just as these were becoming somewhat commonplace, lime-sulphur was brought to our aid and with it the added enterprise of the American commercial advertiser.

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[1] See Stone, G. E., and Smith, R. E., Mass. Agr. Exp. Sta. Bul. 79. 1902.

[2] McAlpine, D., Bitter pit investigations—First progress report. Melbourne.

Please do not misunderstand me. I recognize clearly that the highest duty in plant pathology is service, and that the chief aim in that service is to lessen loss from plant diseases. The only question is, How can we best serve to this end?

Perhaps as conditions have been, we could not at the outset have done much better. It was necessary first to educate the public as to the amount of their loss from plant diseases, as to the general nature of the parasites, and as to the great gains from the use of fungicides. In order to do this, the pathologist must familiarize himself with these things by repeated observations and trials and must contribute in turn to the education of the horticulturist, the agronomist, and the agricultural press. This has taken time—in many cases nearly all of his time; but we may have satisfaction in the idea that it has been well done. No other country has had like service and in no other country has the agricultural public followed the teachings so fully.

It is important, however, for us to remember that this is the pioneer service, necessary and best at the outset; but that, as fast as conditions permit, we must be moving on to the attack on the more fundamental problems, to the performance of the more enduring service. The fundamental idea in plant disease control is prevention. It is surprising, if one goes over the list, how many diseases can not be prevented by the use of fungicides. For the great classes of bacterial diseases, rusts, and soil fungi, we must look to other measures. The three fundamental ideas which here deserve increased attention are sanitation, exclusion, disease resistance.

Spraying and seed treatments are only one part of sanitation in any case and have no part in many cases. Full data as to the life histories and modes of dissemination of causal organisms are more important fundamentals for improved sanitation than are further demonstrations with fungicides. The importance of fertilization, cultivation, and crop rotation in relation to sanitation, together with the destruction of diseased plant tissues and the checking of the carriers of disease germs, deserve more critical attention than they have received from plant pathologists as well as plant cultivators.

While America has for some time been the most advanced nation in controlling diseases by spraying, she has been one of the slowest to undertake plant disease exclusion. The plant quarantine act secured last year by the combined efforts of phytopathologists and entomologists marks, therefore, a most important forward step. The recent hearings relative to the potato disease quarantine, under this act, have served not only to emphasize its importance, both commercially and educationally, but also to point out important new duties for plant pathologists. In order wisely to administer such quarantine measures, there must be international cooperation among phytopathologists in determining the occurrence and seriousness of plant diseases. But while we are thus beginning to guard our borders against potato wart and other dangerous foreign diseases, what are we doing within our own territory? For example, we know that there is an alfalfa disease (*Urophlyctis alfalfæ*) similar to the black wart of potato in its nature and destructive possibilities, as yet apparently limited in its distribution to a few western alfalfa-growing sections.[1] No official steps have as yet been taken, so far as I know, to make exact determinations of its present distribution or to guard against its being carried to other places on seed. This would seem to be a National rather than a State function and the National plant disease survey already referred to would seem to be the logical first step. In this connection the plan outlined by Orton for official inspection and certification as to health of seed potatoes is highly significant.[2] I believe it must commend itself for adoption with various other crops as well. There is no other place more important for guarding the health of crops than at the source of seed.

And finally, there is the question of disease resistance and immunity. Of course, the idea is not new; observations upon the relative liability of varieties to disease come to us from early times. But the clearer conception of the possibilities in this respect of plant improvement through breeding is recent. The relative success of the

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[1] O'Gara, P. J., Urophlyctis alfalfæ, a fungous disease of alfalfa. Science, N. S. 36: 487. 1912.

[2] Presented in a paper, "A Plan of Potato Seed Inspection," before the annual meeting of the Wisconsin Potato Growers' Association, Nov. 20, 1913. See abstract in bulletin issued by J. G. Milward, secretary, Madison, Wis., "Potato Development Work in Wisconsin," p. 49, issued April, 1914.

German and Scotch breeders in securing disease resisting potatoes is fully recognized.[1] The work started by Ward at Cambridge has raised our hopes relative to the possibilities of placing the studies of disease resistance on a scientific basis. The most stimulating results in America have dealt with resistance to soil fungi including Orton's work on cowpea, cotton and watermelon in the South, and Bolley's work on flax in Dakota. Such results as these and Norton's on asparagus rust resistance are to be regarded, not as final, but as merely suggestive of what I believe to be the most important future line of work in the control of plant disease, the breeding and selection of plants for local adaptation and disease resistance. If this is true then the fundamental problem deserving most serious consideration is, What constitutes disease-resistance? The difficulty of even defining the factors involved should not deter us from urging its importance and encouraging work upon it along all possible lines of attack.

IX.—CONCLUSION.

In conclusion let us emphasize that, if progress in plant pathology is to continue as rapidly as we hope, those who are responsible for its direction should realize the limitations of the individual workman, and the necessity for division of the labors involved.

The demand to-day upon the American phytopathologist is almost equally urgent for four types of service—(1) college teaching, (2) extension teaching, (3) inspection, (4) research. In how far are these compatible?

The ideal college teacher must be an investigator, but until we have passed the present stage of rapid growth in our State colleges, nothing comparable to the proper proportions in the division of his energies between these fields is practicable. The duties of public adviser or extension service in plant pathology may not be wholly incompatible with college teaching or station research, although at times seriously distracting. I am, however, convinced that in such matters the professional plant pathologist may in general wisely delegate the responsibility to act as spokesman to his associates in horticulture and agronomy. The nature of a disease and its mode of control once settled, the application of control measures becomes simply one factor in the complex of cultural operations for the execution of which the above departments become responsible.

Plant disease surveys, inspection and quarantine service belong in still another class and deserve the attention of experts in plant pathology. But back of all these must stand the investigator, with time and faculties kept free for his fundamental work; for research is the most exacting of all taskmasters. While no one realizes more keenly than I do the present impracticability, in general, of restricting our responsibilities along any such clean cut lines, nevertheless I am convinced that it is only as we clearly define these ideals and approach more nearly their realization that we are to secure the best results. It is encouraging, therefore, that these responsibilities are being divided in an increasing number of State institutions and that the proposed reorganization in the United States Department of Agriculture follows similar lines, differentiating research at least from the other fields of work.

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[1] See Stuart, Wm., Disease resistance of potatoes. Vt. Agr. Exp. Sta. Bul. 122. 1906.

If in this overlong discussion I have taxed your patience by emphasizing more the problems than the progress in plant pathology, it has been with a two-fold purpose. On the one hand, I have hoped thus to win your continued charity toward the plant pathologist, in view of the complexity of the problems which he must meet, administratively as well as scientifically. On the other, I have wished to urge your continued cooperation along the two lines; first, in training young men for the profession—the best training our botanical institutions can give, with increasing attention to physiology; and second, in sharing, in the future as in the past, in the responsibility for focusing attention upon the fundamental problems and fixing standards by which rightly to measure progress toward their solution.

PLANT-AUTOGRAPHS AND THEIR REVELATIONS.[1]

By Prof. JAGADIS CHUNDER BOSE, M. A., D. Sc., C. S. I., C. I. E.,
Professor, Presidency College, Calcutta.

There are professors of sciences bordering on the mystical, who declare that they can discriminate the character and disposition of anyone, simply by a careful observation of his handwriting. As to the authenticity of such claims scepticism is permissible; but there is no doubt that one's handwriting may be modified profoundly by conditions, physical and mental. There still exist at Hatfield House, documents which contain the signatures of no less a person than the historical Guy Fawkes of Gunpowder Plot celebrity. And those who have seen them declare that there is a sinister variation in these signatures. The crabbed and distorted characters of the last words Guy Fawkes wrote on earth—as in the dark hours of the morning on which he was executed he set his hand to the written confession of his crime—tell their own tale of what had transpired in the solitary imprisonment of that fateful night.

Such, then, is the history that may be unfolded to the critical eye by the lines and curves of a human autograph. Under a placid exterior, there is also a hidden history in the life of the plant. Storm and sunshine, warmth of summer and frost of winter, drought and rain, all these and many more come and go about the plant. What coercion do they exercise upon it? What subtle impress do they leave behind? Is it possible to make the plants write down their own autographs, and thus reveal their hidden history? Were this possible, the fact would be fraught with far-reaching consequences.

For about the life reactions of plants, there are contending and irreconcilable hypotheses. Does the plant, like the animal, give an answering twitch to an external shock? Is there any possible relation between plant life and our own? On these points very little is definitely known. For numerous are the experimental difficulties which confront and baffle the investigator.

One school of thinkers, by far the most numerous, would have us believe that some of the most characteristic reactions in the animal are not to be found in the plant; for example, it is urged that, unlike the animal, the majority of plants are insensitive to a blow, exhibiting no shuddering twitch, either mechanical or electrical; and that even in the sensitive Mimosa, an irritation does not cause an excitatory impulse, but a mere hydraulic disturbance. The pendulum then swings from these hasty assumptions to the diametrically opposite extreme. Under these circumstances the clear path is that which leads us away from theory and disputations to find the thread of fact. We must, therefore, abandon all our preconceptions, and put our questions direct, insisting that the only evidence which can be accepted is that which bears the plant's own signature.

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[1] Reprinted by permission from pamphlet copy published by the Royal Institution of Great Britain. Lecture at the Weekly Evening Meeting, Friday, May 29, 1914.

How are we to know what unseen changes take place within the plant? If it be excited or depressed under some special circumstance, how are we, on the outside, to be made aware of it? The only conceivable way would be, if that were possible, to detect and measure the actual response of the organism to a definite testing blow. When an animal receives an external shock, it may answer in various ways; if it has voice, by a cry; if it is dumb, by the movement of its limbs. The external shock is the stimulus; the answer of the organism is the response. If we can find out in the plant the relation between the stimulus and response we shall be able to determine its state of vitality at the moment. In an excitable condition, the feeblest stimulus will evoke an extraordinarily large response; in a depressed state even a strong stimulus evokes only a feeble response; and lastly, when death has overcome life, there is an abrupt end of the power to answer at all.

We might, therefore, have detected the internal condition of the plant, if we could have made it write down its responses. In order to succeed in this, we have, first, to discover some compulsive force which will make the plant give an answering signal; secondly, we have to supply the wherewithal for an automatic conversion of these signals into an intelligent script; and, last of all, we have ourselves to learn the nature of the hieroglyphic.

RESPONSE OF PLANT AND ANIMAL.

In answering the question whether there is a fundamental unity in the response of plant and animal, we have first to find out whether sensitiveness is characteristic of only a few plants or whether all plants and every organ of every plant is sensitive. Then we have to devise apparatus by which visible or invisible reactions are detected and recorded. Having succeeded in this, we have next to survey the characteristic reactions in the animal, and find out whether phenomena corresponding to these may also be discovered in the plant.

Thus, when an animal is struck by a blow, it does not respond at once. A certain short interval elapses between the incidence of the blow and the beginning of the reply. This lost time is known as the latent period. In the plant is there any definite period which elapses between the incident blow and the responsive twitch? Does this latent period undergo any variation as in the animal, with external conditions? Is it possible to make the plant itself write down this excessively minute time interval?

Next, is the plant excited by various irritants which also excite the animal? If so, at what rate does the excitatory impulse travel in the plant? Under what favorable circumstances is this rate of transmission enhanced, and under what other circumstances is it retarded or arrested? Is it possible to make the plant itself record this rate and its variation? Is there any resemblance between the nervous impulse in the animal and the excitatory impulse in the plant?

The characteristic effects of various drugs are well known in the case of the animal. Is the plant similarly susceptible to their action? Will the effect of poison change with the dose? Is it possible to counteract the effect of one poison by means of another?

In the animal there are certain automatically pulsating tissues like the heart. Are there any such spontaneously beating tissues in the plant? If so, are the pulsations in the animal and the plant affected by external conditions in a similar manner? What is the real meaning of spontaneity?

Growth furnishes us with another example of automatism. The rate of growth in a plant is far below anything we can directly perceive. How, then, is this growth to be magnified so as to be rendered instantly measureable? What are the variations in this infinitesimal growth under external stimulus of light and shock of electric current? What changes are induced by giving or withholding food? What are the conditions which stimulate or retard growth?

And, lastly, when by the blow of death life itself is finally extinguished, will it be possible to detect the critical moment? And does the plant then exert itself to make one overwhelming reply, after which response ceases altogether?

PLANT SCRIPT.

We shall first take up the question of recording response of a plant like Mimosa. Here, at the joint of the leaf, there is a cushion-like mass of tissue known as the pulvinus. This serves as the motile apparatus. The swollen mass on the lower side is very conspicuous. Under excitation, the parenchyma in this more effective lower half undergoes contraction, in consequence of which there is a fall of the leaf. This sudden movement constitutes the mechanical response of the leaf to the impinging stimulus, just as the contractile movement of a muscle in similar circumstances forms its characteristic mechanical response. For obtaining a record, the leaf of Mimosa is attached to one arm of a lever, V; the other is loaded with a small weight, which acts as a counterpoise. A long wire, W, bent at the tip, is placed at right angles to the lever, and serves as a writer. The tip of this writer touches a smoked-glass plate, which is allowed by means of a clockwork to fall at a definite rate. (Fig. 1.) An instantaneous electric shock is applied on the leaf stalk at A. The excitation will, after a time, be propagated from A to the responding pulvinus at B, inducing the responsive fall of the leaf. After a definite period the leaf recovers from excitations and is reerected. A complete curve of response is thus obtained in which the ordinate *a b* represents the intensity of excitation, and the abscissa *a c* the period of complete recovery. (Fig. 2.) Any condition which increases excitability will also enhance the amplitude of response. Depression, on the other hand, is attended by a diminution of response. At death the response is altogether abolished. Thus, by means of testing blows, we are able to make the plant itself reveal those invisible internal changes which would otherwise have entirely escaped us.

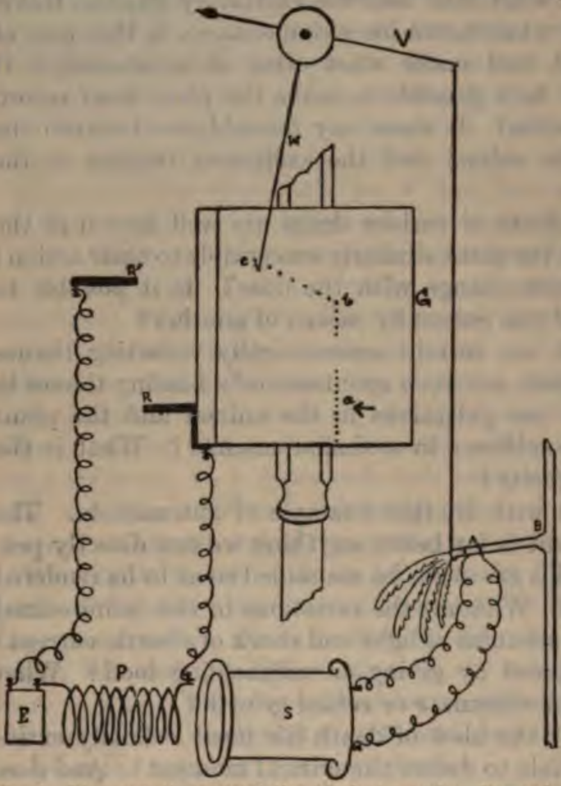

FIG. 1.—Diagrammatic representation of plant recorder. Responding leaf attached to one arm of lever V, at the fulcrum of which is attached W, the writer. G, sliding smoked glass plate for record. Recording plate is lifted and allowed to drop. At a definite position during fall, R makes momentary electric contact with R', giving rise to instantaneous electric shock at A. Moment of application of stimulus marked on recording plate by arrow *a;* arrival of excitation at B causes fall of leaf, which pulls the writer to left, describing *bc.* For determination of latent period, stimulus is applied on the pulvinus at B.

The above is a description of the theoretical method of obtaining response of the plant. In practice numerous difficulties have to be overcome. In the case of muscle-contraction, the pull exerted is considerable and the friction offered by the recording surface constitutes no essential difficulty. In the case of plants, however, the pull exerted by the motile organ is relatively feeble, and in the movement of the very small leaflets of *Desmodium gyrans* or the telegraph plant, for instance, a weight so small as four-hundredths of a gram is enough to arrest the pulsation of the leaflets. Even in the leaf of Mimosa the friction offered is enough to introduce serious errors into the amplitude and time relations of the curve. This error could not be removed as long as the writer remained in continuous contact with the writing surface. I was, however, able to overcome this difficulty by making an intermittent, instead of a continuous, contact. The possibility of this lay in rendering the writer tremulous. Fresh difficulties arose which were finally eliminated by an invention depending on the phenomenon of resonance.

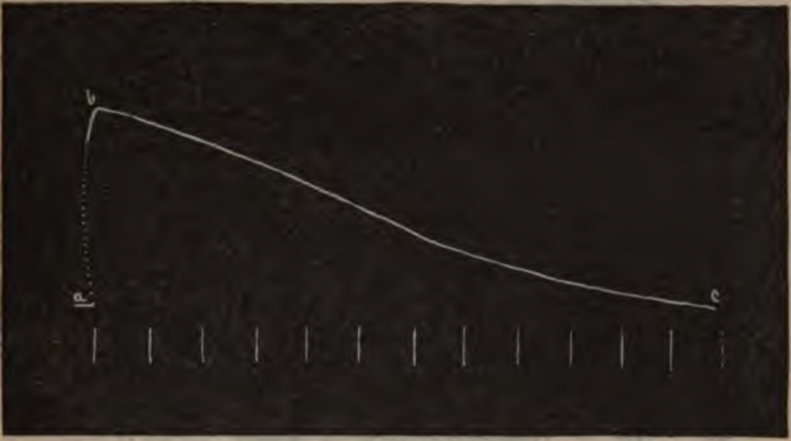

FIG. 2.—Response curve of primary leaf of Mimosa. The vertical lines below the record indicate intervals of one minute each.

THE RESONANT RECORDER.

The principle of my resonant recorder depends on a certain phenomenon, known as resonance or sympathetic vibration. In illustration of this we may construct an artificial ear tuned to a definite note. The drum of the artificial ear is made of thin soap film; a beam of light reflected from its surface forms characteristic pattern of color on the screen. To various cries this ear remains deaf, but the apathy disappears as soon as the note to which the ear is tuned is sounded at a distance. On account of sympathetic vibration the artificial ear film is thrown into wildest commotion, and the hitherto quiescent color pattern on the screen is now converted into a whirlpool of indescribably gorgeous color of peacock green and molten gold.

In the same manner, if the strings of two violins are exactly tuned, then a note sounded on one will cause the other to vibrate in sympathy. We may likewise tune the vibrating writer V with a reed C. (Fig. 3.) Suppose the reed and the writer are both tuned to vibrate a hundred times per second. When the reed is sounded the writer will also begin to vibrate in sympathy. In consequence of this the writer will no longer remain in continuous contact with the recording plate, but will deliver a succession of taps a hundred times in a second. The record will therefore consist of series of dots, the distance between one dot and the next representing one-hundredth part of a second. With other recorders it is possible to measure still shorter intervals. It will now be understood how, by the device of the resonant recorder, we not only get rid of the error due to friction, but make the record itself measure time as short as may be desired. The extraordinary delicacy of this instrument will be understood when by its means it is possible to record a time-interval as short as the thousandth part of the duration of a single beat of the heart. The complete apparatus for obtaining plant record is shown in figure 4.

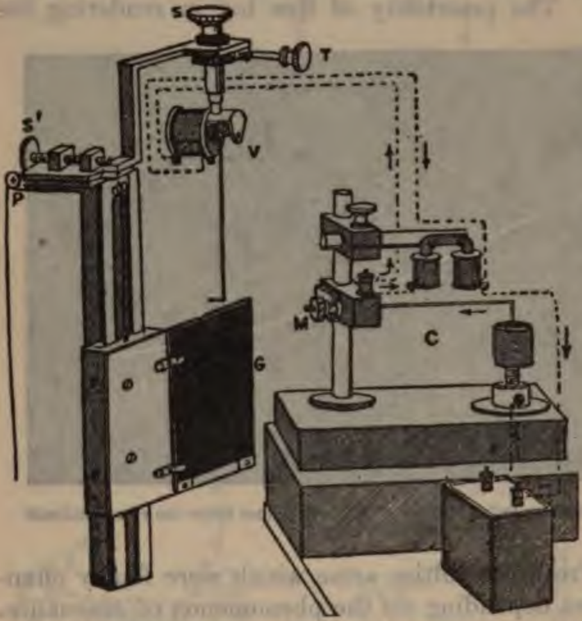

FIG. 3.—Upper part of resonant recorder (from a photograph). Thread from clock (not shown) passes over pulley P, letting down recording plate. S′, screw for adjustment of distance of writing-point from recording plate. S, screw for vertical adjustment. T, tangent screw for exact adjustment of plane of movement of recorder, parallel to writing surface. V, axis of writer supported perpendicularly at center of circular end of magnet. C, reed. M, micrometer screw for adjustment of length of reed.

COMPARISON BETWEEN SENSITIVENESS OF MAN AND PLANT.

We have next to find some method of stimulation which will not cause any mechanical disturbance to the plant. In connection with this I made an important discovery which demonstrates the identical characteristics of excitation in plant and animal. In the animal tissue a constant electric current causes very characteristic excitations at the moment of "make" or "break" of the current. In most cases there is no excitation during the continuation of the current. At the "make" excitation takes place only at the cathode; at the "break" of the current, however, excitation is induced once more, but this time at the anode. These characteristic effects I find repeated also in the plant. At this point it is interesting to institute a comparison between the sensitiveness of a plant and a human being. The most sensitive organ by which an electric current can be detected is our tongue. An average European, according to Laserstein, can perceive by his tongue a current as feeble as 6.4 microamperes—a microampere being one-millionth part of the unit of current. This value might be subject to certain variation, depending on racial characteristics. One might expect that the tongue of the Celt would be far more excitable than that of the stolid Anglo-Saxon. In any case the superiority of man has to be established on foundations more secure than sensibility; for the plant Biophytum, I find, is

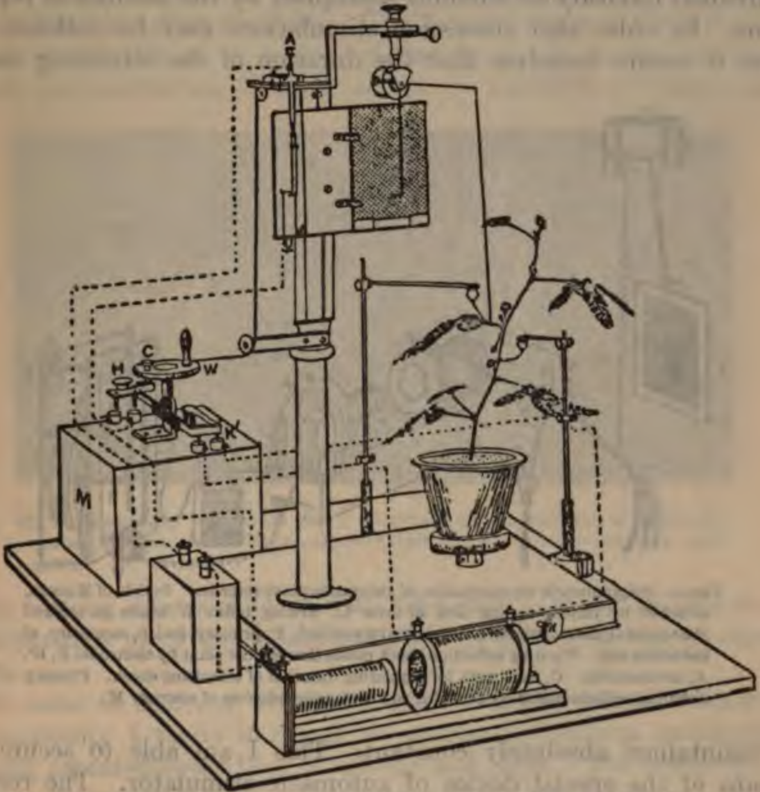

FIG. 4.—Apparatus for determination of latent period of Mimosa. M, spring motor. W, winding disk. C, projecting catch. H, release handle, pressure on which also completes primary circuit of induction coil. K', short circuit key. The automatic break consists of contact rod adjusted by micrometer screw A.

eight times more sensitive to an electrical current than a human being. With regard to the stimulus of induction shock, Mimosa is ten times as sensitive. As with the animal so also with the plant, the effect of stimulus is additive; that is to say, effective stimulation is determined not only by the intensity, but also by the duration of application. In fact, I have been able to establish in plants a strictly quantitative relation as regards the additive effect of subminimal stimulus, which is, that the effective excitation is equal to individual intensity of stimulus multiplied by the number of repetitions. In order that successive stimulations may be uniform, we have to assure ourselves that the duration of the tetanizing shock is maintained absolutely constant. This I am able to secure by means of the special device of automatic stimulator. The results of experiments to be presently described appeared so astonishing that for many reasons it became highly desirable to remove completely all elements of personal equation. In fulfilment of this, I spent several years in perfecting various instruments by which the plant attached to the recording apparatus is automatically excited by successive stimuli which are absolutely constant. In answer to this it makes its own responsive records, goes through its period of recovery, and embarks on the same cycle over again, without assistance at any point from the observer. (Fig. 5.) In this way the effect of changed external condition is seen recorded in the script made by the plant itself.

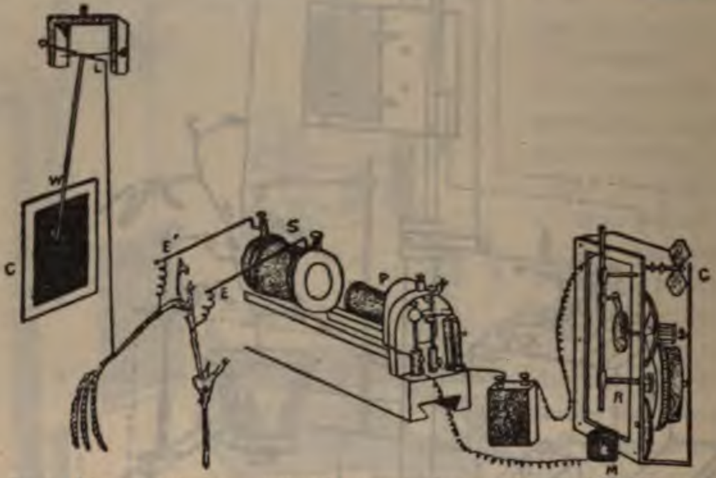

FIG. 5.—Diagrammatic representation of automatic plant-recorder. Petiole of Mimosa, attached by thread to one arm of lever L; writing index W traces on smoked glass plate G the responsive fall and recovery of leaf. P, primary, and S, secondary, of induction coil. Exciting induction shock passes through the plant by electrodes E, E′. A, accumulator. C, clockwork for regulating duration of tetanizing shock. Primary circuit of coil completed by plunging rod R dipping into cup of mercury M.

THE SLEEP OF PLANTS.

In studying the effect of a given change in the external condition an assumption has to be made that during the time of experiment there has been no spontaneous variation of excitability. Is the plant equally excitable throughout day and night? If not, is there any particular period at which the excitability remains uniform? Is there again a different time during which the plant loses its sensibility—going, as it were, to sleep? On these points no definite information has been available. The fanciful name of sleep is often given to the closure of leaflets of certain plants during darkness. These movements are brought about by variation of turgor, and have nothing whatever to do with true sleep; for similar closure of leaflets takes place under the precisely opposite condition of strong light.

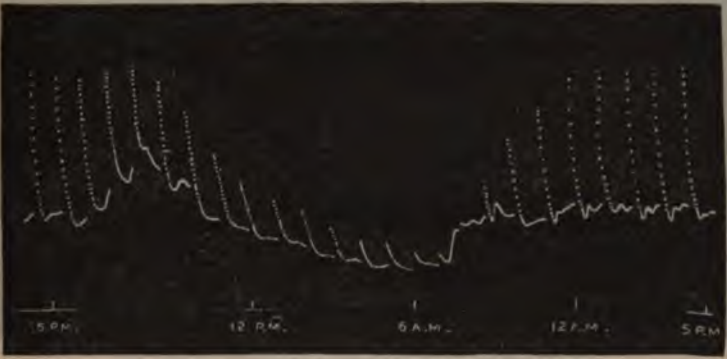

FIG. 6.—Record for twenty-four hours, exhibiting diurnal variation of excitability (spring specimen). The displacements of base line are due to nyctitropic movements.

In order to find out whether Mimosa exhibits diurnal variations of sensibility I made it record its answer to uniform questioning shocks, repeated every hour of the day and night. The amplitude of the answering twitch gave a measure of the "wakefulness" of the plant during 24 hours. The results obtained were quite unexpected. The plant is found to keep up very late, and fall asleep only at the early hours of the morning. It makes up for its late hours by gradually waking up by noon. (Fig. 6.) It then remains in a condition of uniform sensibility all the afternoon. This period of uniformity is chosen for investigations on the effect of changed external conditions on excitability.

EFFECT OF LIGHT AND TEMPERATURE.

Does the plant feel the depressing effect of darkness? The following record shows the effect of a passing cloud. (Fig. 7.) It is the sudden change which exerts a marked depressing effect. The plant partially regains its sensibility when accustomed to darkness. When brought suddenly from darkness to light there is also a transient depression followed by enhanced excitability.

Temperature has also a marked effect on excitability. Up to a critical point warmth increases excitability, the recovery being also hastened. Cooling conversely depresses excitability. The motile excitability is abolished at about 20° C.

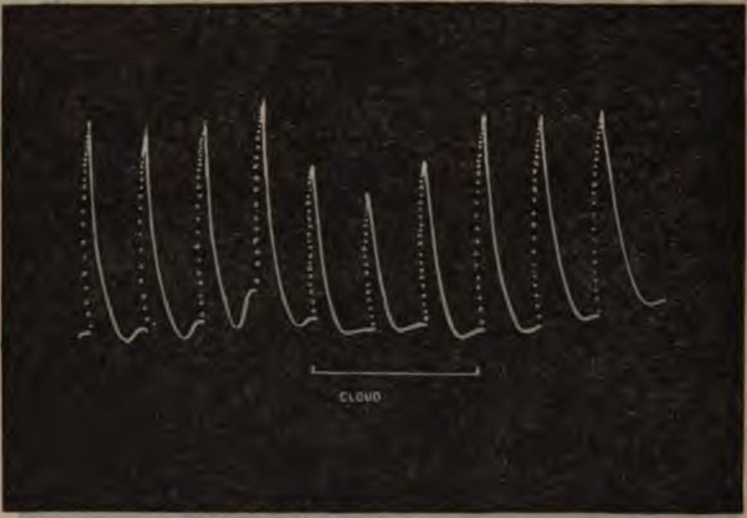

FIG. 7.—Effect of cloud. Dotted up-curve indicates responsive fall, and continuous down-line exhibits slow recovery. First four responses normal; next three show depression due to diminution of light brought on by cloud, the duration of which is indicated by horizontal line below. Last three records show restoration of excitability brought on by clearing of sky. All records read from left to right.

EFFECT OF AIR, FOOD, AND DRUGS.

The plant is intensely susceptible to the impurities present in the air. The vitiated air of the town has a very depressing effect. According to popular science, what is death to the animal is supposed to be life for the plant; for does it not flourish in the deadly atmosphere of carbonic acid gas? The record (fig. 8) shows that, instead of flourishing, the plant gets suffocated just like a human being. Note the gasp of relief when fresh air is introduced. Only in the presence of sunlight is the effect modified by photosynthesis. In contrast to the effect of carbonic acid, ozone renders the plant highly excitable. Sulphuretted hydrogen, even in small quantities, is fatal to the plant. Chloroform acts as a strong narcotic, inducing a rapid abolition of excitability. The ludicrously unsteady gait of the response of plant under alcohol (fig. 9) could be effectively exploited in a temperance lecture. The next record is in the nature of an anticlimax, where the plant has drunk (pure water) not wisely but too well. The gorged plant is seen to have lost all power of movement. I was, however, able to restore the plant to normal condition by extracting the excess of liquid by application of glycerin. (Fig. 10.)

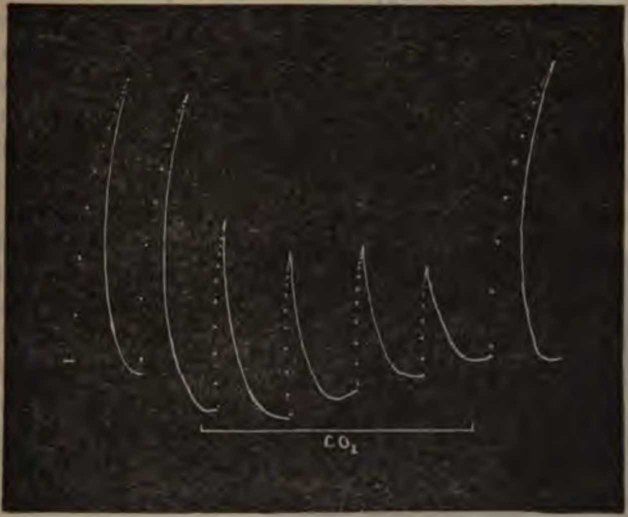

FIG. 8.—Effect of carbonic acid gas.

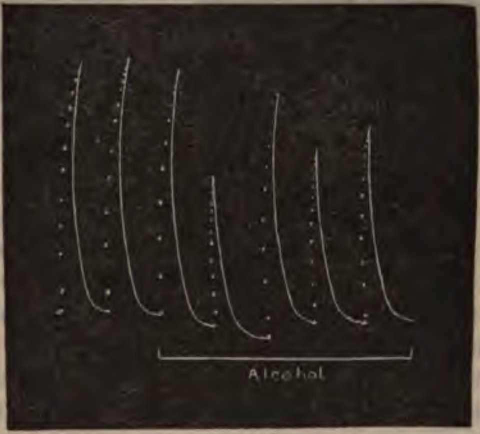

FIG. 9.—Effect of vapor of alcohol.

UNIVERSAL SENSITIVENESS OF PLANTS.

It may be urged that the various reactions of irritability may hold good only in the case of the particular plant Mimosa, and that the majority of plants are quite insensitive. I shall presently show that this view is quite erroneous. In Mimosa diffuse stimulation causes relatively greater contraction of the more excitable lower half of the pulvinus, and this differential action is magnified by the long petiolar index. Had the upper half of the pulvinus been equally excitable as the lower, then the antagonistic reactions would have balanced each other. In radial organs we do not observe any lateral movement as in Mimosa. This is not owing to insensitiveness, but to equal contractions on all sides balancing each other. The shortening of length of various radial organs like soft stem, tendril, pistil, and stamen, can easily be shown by means of magnifying levers. Again, if we take a hollow tubular organ of some ordinary plant, say the peduncle of daffodil, it is clear that the protected inner side of the tube must be the more excitable. When this is cut in the form of a spiral strip and excited by means of an electric shock, we observe a responsive movement by curling, brought about by greater contraction of the inside of the strip. If again we take a tendril which has curled round a support, the outside is fresh and free from irritation and therefore more excitable. In this case the response is by uncurling, due to greater contraction of the more excitable outer side of the spiral.

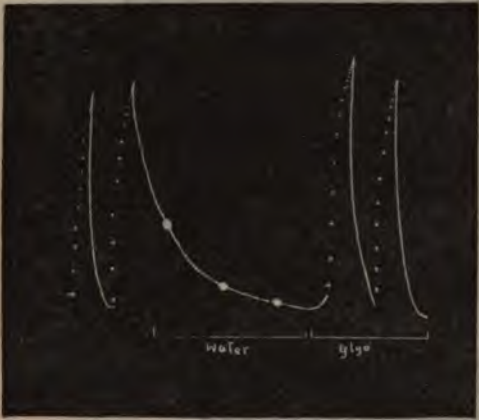

FIG. 10.—Abolition of motile excitability by excessive absorption of water, and subsequent restoration by withdrawal of excess.

In the case of woody plants, responsive movement is prevented by the rigid support. Even in such a case I have been able to demonstrate its excitation by means of electric response, first exhibited at this very hall 13 years ago.[1] No plant could appear more stolid and irresponsive than the common radish; appearances are, however, deceptive, and we find it giving a series of vigorous responses in answer to successive stimuli. The electric response comes to an end with the death of the plant.

LATENT PERIOD OF PLANT.

I next take up the very difficult problem of finding out how long it takes for the plant to perceive and respond to a blow. In attempting to make such measurements the results are vitiated by our personal limitations. The conditions of the experiment demand accurate measurements of time-intervals shorter than a hundredth part of a second; but sluggishness of our perception makes such an attempt an impossibility. It is therefore absolutely necessary to invent a special device by which the plant itself should be compelled to write down its own latent period. In the case of the leg muscle of a frog the latent period, according to Helmholtz, is about a hundredth part of a second. This result is not without some error, on account of the inertia of the recording lever, and the inferring of time relations from a neighboring chronographic record. In my resonant recorder these errors have been reduced to a minimum. In the first place, the curve of response or phytogram is at the same time a chronogram. Secondly, the weight of my plant recorder is only a hundredth part of the usual muscle recorder. The latent period of the animal tissue undergoes appropriate variation with changing external conditions. With feeble stimulus it has a definite value; this becomes shortened under a stronger blow. Again, when we are tired our perception time becomes prolonged. Every one of these results is equally applicable in the case of the plant. The delicacy of the resonant recorder will be understood from the response curve exhibiting the latent period of Mimosa (fig. 11). Here determination is carried to a thousandth part of a second, the value being 0.076 seconds, or eight times its value in an energetic frog. The reliability of this method can be gauged from successive records under uniform conditions, when the results are found to be identical. Another curious thing is that a stoutish plant will give its response in a slow and lordly fashion, whereas a thin one attains the acme of its excitement in an incredibly short time. Perhaps some of us can tell from our own experience whether similar differences obtain among human kind. The perception time of the plant becomes

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[1] Bose—Friday evening discourse, May 10, 1901.

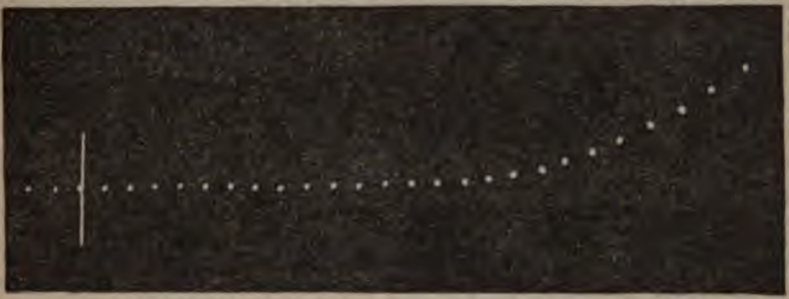

FIG. 11.—Record showing the latent period of Mimosa. This recorder vibrates 200 times per second. The time-interval between successive dots is here 0.005 sec.

very sluggish under fatigue; when excessively tired it temporarily loses its power of perception. In this condition the plant requires at least half an hour's absolute rest to regain its equanimity.

EXCITATORY IMPULSE IN MIMOSA.

We next take up the question of the function of transmission of excitation. It has hitherto been supposed that in Mimosa the impulse caused by irritation is merely hydromechanical and quite different from the nervous impulse in the animal. According to this hydromechanical theory, the turgid plant tissue is imagined to be like india-rubber tube filled with water. The application of mechanical stimulus is supposed to squeeze the tissue, in consequence of which the water forced out delivers a mechanical blow to the contractile organ of the plant. The propagation of mechanical disturbance is thus occasioned by the bodily transfer of fluid material in a pipe. In strong contrast to this is the transmission of nervous impulse, which is a phenomenon of passage of protoplasmic disturbance from point to point. The molecular disturbance, constituting excitation, passes along the conducting nerve, and this point-to-point propagation of molecular upset is known as the transmission of excitatory or nervous impulse. If by any means the physiological activity of a portion of the nerve be enhanced, then excitation will pass through the particular portion with quickened speed. Such favorable condition is brought about by the application of moderate warmth. If a portion of nerve, on the other hand, be rendered physiologically sluggish, then the speed of nervous impulse through that portion will be slowed down. There are certain agents which paralyze the nerve for the time being, causing a temporary arrest of the nervous impulse. Such agents are known as anesthetics. There may, again, be poisonous drugs which destroy the conducting power. Under the action of such poisonous agents the nervous conduction is permanently abolished.

We are now in a position to distinguish between mechanical and nervous transmission. The mechanical conduction of water through a pipe will in no way be affected by warmth or cold; the pipe will not lose consciousness and stop the flow of water, if it be made to inhale chloroform, nor will its conducting power be abolished by applying round it a bandage soaked in poison. These agents will, on the other hand, profoundly affect the transmission of excitation. The nature of an impulse may thus be discriminated by several crucial tests.

If physiological changes affect the rate of conduction, then the impulse must be of a nervous character; absence of such effect, on the other hand, proves the mechanical character of the impulse.

Of the various physiological tests, Pfeffer employed that of the narcotic drug. Chloroform applied on the surface of the stem of Mimosa failed to arrest the impulse. This result, at first sight, appears most convincing and has been universally accepted as a disproof of the existence of nervous impulse in Mimosa. A little reflection will, however, show that under the particular conditions of the experiment the conducting tissue in the interior could not have been affected by the external application of the narcotic, the task being, in fact, as difficult as narcotizing a nerve trunk lying between muscles by the application of chloroform on the skin outside.

The question of nervous impulse in plants has thus to be attacked anew, and I have employed for this purpose twelve different methods. They all prove conclusively that the impulse in the plant is identical in character with that in the animal. Of these I shall give a short account of three different modes of investigation. It is obvious that the transmitted impulse in Mimosa must be of an excitatory, or nervous, character:

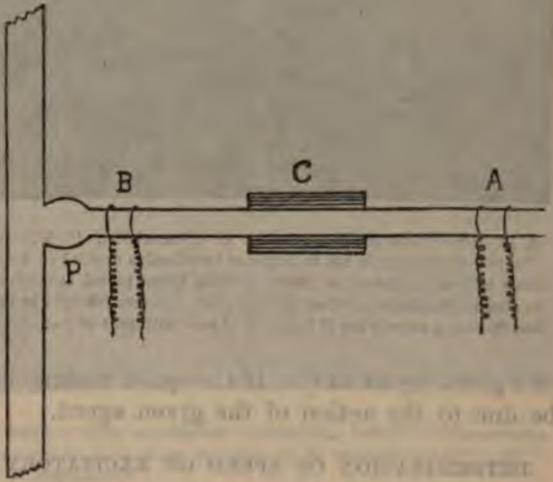

Fig. 12.—Experimental arrangement for determination of velocity of transmission and its variation. Record is first taken when stimulus is applied near the pulvinus at B (latent period) and then at a distant point on the leaf-stalk at A. Difference of two gives time for transmission from A to B. The band of cloth C is for local application of warmth, cold, anesthetics, and poison.

(1) If excitation can be initiated and propagated without any physical disturbance. The central fact in the mechanical theory is the squeezing out of water for starting the hydraulic impulse. The hydromechanical theory must necessarily fall to the ground if excitation can be effected without any mechanical disturbance whatsoever. I have shown that excitatory impulse is initiated under the polar action of current in the complete absence of any mechanical disturbance, the intensity of the current being so feeble as not to be perceived even by the very sensitive human tongue.

(2) If it can be shown that physiological changes induce appropriate variation in the velocity of transmission of the impulse.

(3) If the impulse in the plant can be arrested by different physiological blocks by which nervous impulse in the animal is arrested.

For the last two investigations the research resolves itself into the accurate measurement of the speed with which an impulse in the plant is transmitted, and the variation of that speed under changed condition. A portion of the tissue at C may, for example, be subjected to the action of cold or of a poison (fig. 12). In order to find the speed of normal transmission, we apply an instantaneous stimulus, say, of an electric shock, at B, near the pulvinus. A short interval, the latent period, will elapse between the application of stimulus and the beginning of responsive movement. After the determination of the latent period we apply stimulus once more at A and observe the time which elapses between the application of stimulus and the response. The difference between the two periods gives us the time required for the excitation to travel from the point of application of stimulus at A to the responding organ at B. Hence we obtain the speed of impulse in the plant. The experiment is repeated once more after the application of a given agent at C. If the speed undergoes any variation, it must be due to the action of the given agent.

FIG. 13.—Determination of velocity of transmission in Mimosa. The two lower records are in response to stimulus applied at a distance of 30 mm.; the upper record exhibits latent period in response to direct stimulus applied on the pulvinus. Successive dots in this and following records are of intervals of one-tenth part of a second.

DETERMINATION OF SPEED OF EXCITATORY IMPULSE IN PLANTS.[1]

As relatively long intervals have to be measured in the determination of velocity, the recorder has its frequency adjusted to 10 vibrations per second, hence the space between successive dots represents an interval of one-tenth of a second. In figure 13 is given a record for determining the velocity of transmission. The two lower figures give practically identical results of successive experiments when stimulus was applied at a distance of 30 millimeters. The uppermost is the record for direct stimulation. From these it is seen that the interval between stimulus and response is 1.6 seconds, and that the latent period is 0.1 second. Hence the true time for the excitation to travel through a distance of 30 millimeters is 1.5 seconds, the velocity being 20 millimeters per second.

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[1] For a more detailed account confer:
Bose, An automatic method for the investigation of velocity of transmission of excitation in Mimosa Phil. Trans. of Royal Society, Series B, Vol. 204.
Bose, Researches on irritability of plants (Longmans Green, 1913).

The velocity of excitatory impulse in the plant is slower than those of higher, but quicker than those of lower animals. The speed of the impulse is, however, subject to variation under different conditions. One significant result that came out was that while a plant carefully protected under glass from outside blows looked sleek and flourishing, yet as a complete and perfect organism it proved to be a failure. Its conducting power was found atrophied or paralyzed. But when a succession of blows rained on this effete and bloated specimen, the stimulus canalized its own path of conduction and it became more alert and responsive, and its nervous impulses became very much quickened.

INFLUENCE OF TEMPERATURE ON VELOCITY.

A decisive experiment to discriminate between the theories of mechanical and nervous transmissions consists in the determination of the effect of temperature on the speed of transmission. Temperature has no effect on mechanical propagation, whereas a moderate variation of it profoundly affects nervous transmission. The result given in figure 14 is quite conclusive as regards the excitatory character of the impulse in plants. It is seen that with rising temperature the time required for transmission through the same distance is continuously reduced. In the present case the velocity is seen to be more than doubled by a rise of temperature through 9°.

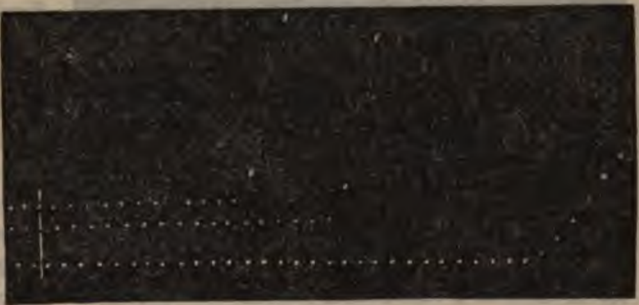


FIG. 14.—Effect of rising temperature in enhancing velocity of transmission. The three records from below upwards are for temperatures 22° C., 28° C., and 31° C., respectively.

The converse experiment is to subject a portion of conducting petiole to the action of cold. This retards the speed of conduction. Excessive cold temporarily abolishes the conducting power.

INDUCED PARALYSIS AND ITS CURE BY ELECTRIC TREATMENT.

As an aftereffect of the application of intense cold, the conducting power remains paralyzed for a considerable length of time. It is a very interesting and suggestive fact that I have been able to restore the conducting power quickly by subjecting the paralyzed portion of the plant to a measured and moderate dose of electric shock. The application of too strong an intensity is, however, very detrimental.

BLOCK OF CONDUCTION BY THE ACTION OF POISON.

I have also succeeded in arresting conduction of excitation in plants by local application of poisonous drugs. The defect of Pfeffer's experiment lay in his attempt to arrest the impulse by the application of a volatile anesthetic like chloroform on a surface of a thick stem. The chloroform escapes in the form of vapor; the access of the solution under these conditions to the interior of the tissue by absorption can only be slight and therefore ineffective in arresting the excitatory impulse. It occurred to me that the physiological block induced by a drug could be rendered more effective in two different ways: First, by the selection of a thin leaf stalk instead of a thick stem for the purpose of the experiment, so that the access of the solution to the interior became less difficult; in the second place by the employment of strong nonvolatile toxic agents, like solutions of copper sulphate or of potassium cyanide. The choice of a strong poison was deemed advisable, because the absorption of even a small quantity might in such a case prove effective in abolishing the conducting power. My anticipations were fully justified. By the application of copper sulphate the conducting power was found arrested in the course of 20 minutes; but the more deadly cyanide solution abolished the conducting power in a period as short as five minutes. (Fig. 15.)

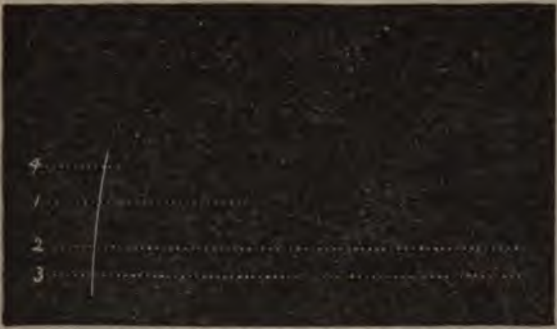


FIG. 15.—Abolition of conduction by local application of potassium cyanide. (1) Normal record; (2) arrest of conduction after application for five minutes; (3) persistent abolition of conduction, even when stimulus was increased fifteen-fold; (4) record of direct stimulation.

Accounts have thus been given of some typical experiments by which the nervous impulse is discriminated from the mechanical impulse. It has been shown that excitation may be initiated and transmitted in the plant in the complete absence of any mechanical disturbance. It has been shown that the various conditions which accelerate, retard, or arrest the nervous impulse in the animal also enhance, retard, or block the impulse in the plant in a manner which is identical. I have, moreover, from my investigations on the plant nerve, led to the discovery of certain hitherto unknown characteristics of the animal nerve. The investigation on the simplest type of plant nerve is expected to cast a flood of light on the obscure phenomenon of nervous impulse in general and the causes operative in bringing about the degeneration of the normal function of the nerve.

SPONTANEOUS PULSATION.

In certain animal tissues a very curious phenomenon is observed. In man and other animals, there are tissues which beat, as we say, spontaneously. As long as life lasts, so long does the heart continue to pulsate. There is no effect without a cause. How, then, was it that these pulsations became spontaneous? To this query no fully satisfactory answer has been forthcoming. We find, however, that similar spontaneous movements are also observable in plant tissues, and by their investigation the secret of automatism in the animal may perhaps be unraveled.

Physiologists, in order to know the heart of man, play with those of the frog and tortoise. "To know the heart," be it understood, is here meant in a purely physical and not in a poetic sense. For this it is not always convenient to employ the whole of the frog. The heart is therefore isolated and made the subject of experiments as to what conditions accelerate and what retard the rate and amplitude of its beat. When thus isolated, the heart tends of itself to come to a standstill, but if by means of a fine tubing it be subjected to internal hydrostatic pressure its beating will be resumed and will continue uninterrupted for a long time. By the influence of warmth the frequency of the pulsation may be increased, but its amplitude diminished. Exactly the reverse is the effect of cold. The natural rhythm and the amplitude of the pulse undergo again appropriate changes under the action of different drugs. Under ether the heart may come to a standstill, but on blowing this off the beat is renewed. The action of chloroform is more dangerous, any excess in the dose inducing permanent arrest. Besides these there are poisons also which arrest the heartbeat, and a very noticeable fact in this connection is that some stop it in a contracted and others in a relaxed condition. Knowing these opposed effects, it is sometimes possible to counteract the effect of one poison by administering another.

RHYTHMIC PULSATIONS IN DESMODIUM.

The existence of such spontaneous movements is seen in the well-known Indian plant *Desmodium gyrans,* or the telegraph plant, whose leaflets dance up and down more or less continuously. The characteristics of the automatic pulsations in the plant could not be determined on account of the apparent impossibility of obtaining a record. The leaflets are too minute and the pull exerted too feeble to overcome friction of the recording surface. This difficulty I have been able to remove by the device of my oscillating recorder. From the records thus obtained I am enabled to say that the automatic movements of both plants and animals are guided by laws which are identical.

Firstly, when for convenience of experiment we cut off the leaflet, its spontaneous movements, like those of the heart, come to a stop. But if we now subject the isolated leaflet by means of a fine tube to an added internal hydrostatic pressure, its pulsations are renewed and continue uninterrupted for a very long time (fig. 16). It is found again that the pulsation frequency is increased under the action of warmth and lessened under cold, increased frequency being attended by diminution of amplitude and vice versa. Under ether there is a temporary arrest, revival being possible when the vapor is blown off (fig. 17). More fatal is the effect of chloroform. The most extraordinary parallelism, however, lies in the fact that those poisons which arrest the beat of the heart in a particular way arrest the plant pulsation also in a corresponding manner, the arrest produced being either at systole or diastole, depending on the characteristic reaction of the poison. Taking advantage of the antagonistic reactions of specific poisons, I have been able to revive a poisoned leaflet by the application of another counteracting poison.

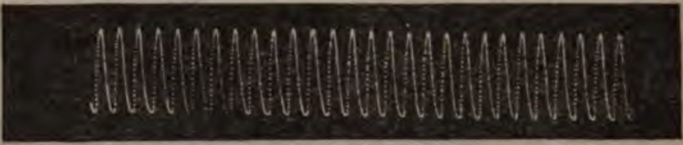


FIG. 16.—Record of automatic pulsations in *Desmodium gyrans*.

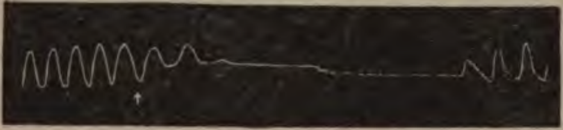


FIG. 17.—Arrest of pulsation of Desmodium under ether; restoration of pulsation on blowing off ether. The arrow indicates the time of application.

Let us now inquire into the causes of these automatic movements, so called. In experimenting with certain types of plant tissues I find that an external stimulus gives rise to the same amplitude of response, whether the stimulus be feeble or strong. What happens, then, to the excess of the incident energy? It is not really lost, for these particular plant tissues have the power of storage. In this way energy derived in various ways from without—such as light, warmth, food, and so on—is constantly being accumulated. When a certain point is reached, there is a bubbling overflow, and we call this overflow spontaneous movement. Thus what we call automatic is really an overflow of what has previously been stored up. When this accumulated energy is exhausted, then there is also an end of spontaneous movements (fig. 18). But a fresh accession of stimulus from outside renews these pulsations.

In the matter of these so-called spontaneous activities of the plant I find that there are two distinct types. In one the overflow is initiated with very little storage, but here the unusual display of activity soon comes to a stop. To maintain such specimens in the rhythmic condition, constant stimulation from outside is necessary. Plants of this type are extremely dependent on outside influences, and when such sources of stimulus are removed they speedily come to an inglorious stop. Averrhoa is an example of this kind. In the second type of automatic plant activity I find that long-continued storage is required before an overflow can begin. But in this case the spontaneous outburst is persistent and of long duration, even when the plant is deprived of any immediately exciting cause. These, therefore, are not so obviously dependent as the others on the sunshine of the world. Our telegraph plant, Desmodium, is an example of this.

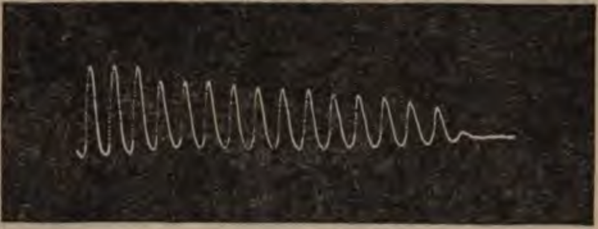


FIG. 18.—Gradual stoppage of pulsation in an isolated Desmodium leaflet due to rundown of stored energy.

INSTANTANEOUS RECORD OF GROWTH.

As a further example of automatic activity we may take the phenomenon of growth. The rate of growth is so extremely slow that even the proverbial pace of the snail is two thousand times quicker. It would take an average plant 200 years to cover the short distance of a mile. This extreme slowness is a serious drawback in the investigation on growth. For even with the existing magnifying growth recorders it would take many hours for the variation of growth to be recorded under the given changed conditions in the environment. The results thus obtained are subject to errors brought about by the variation of growth which takes place spontaneously in the course of a few hours. Growth can be assumed to remain constant only for a short time; on this account it is necessary to conclude an experiment in the course of a few minutes.

By means of microscopic projection it is possible to magnify growth; but such an arrangement will not be self-recording. There is again a serious error introduced by the action of strong light, which profoundly modifies the rate of normal growth.

These difficulties have been overcome in my high magnification crescograph, which records the absolute rate of growth in a time so short as the single beat of the pendulum. The various magnifications available are a thousand or ten thousand times. For demonstration purposes I have been able to secure a magnification of a million times. The infinitesimal growth thus becomes magnified so as to appear rushing forward as if in a race. The actual rate of growth and its variations under the action of drugs, of food materials, of various electrical and other forms of stimuli, are thus recorded in the course of a few minutes. The great importance of this method of investigation in agriculture is sufficiently obvious.

The plant has thus been made to exhibit many of the activities which we have been accustomed to associate only with animal life. In the one case, as in the other, stimulus of any kind will induce a responsive thrill. There are rhythmic tissues in the plant which, like those in the animal, go on throbbing ceaselessly. These spontaneous pulsations in the one case, as in the other, are affected by various drugs in an identical manner. And in the one case, as in the other, the tremor of excitation is transmitted with a definite and measured speed from point to point along conducting channels. The establishment of this similarity of responsive actions in the plant and animal will be found of the highest significance; for we now realize that it is by the study of the simpler phenomena of irritability in the vegetal organisms that we may expect to elucidate the more complex physiological reactions of the animal.

THE PLANT'S RESPONSE TO THE SHOCK OF DEATH.

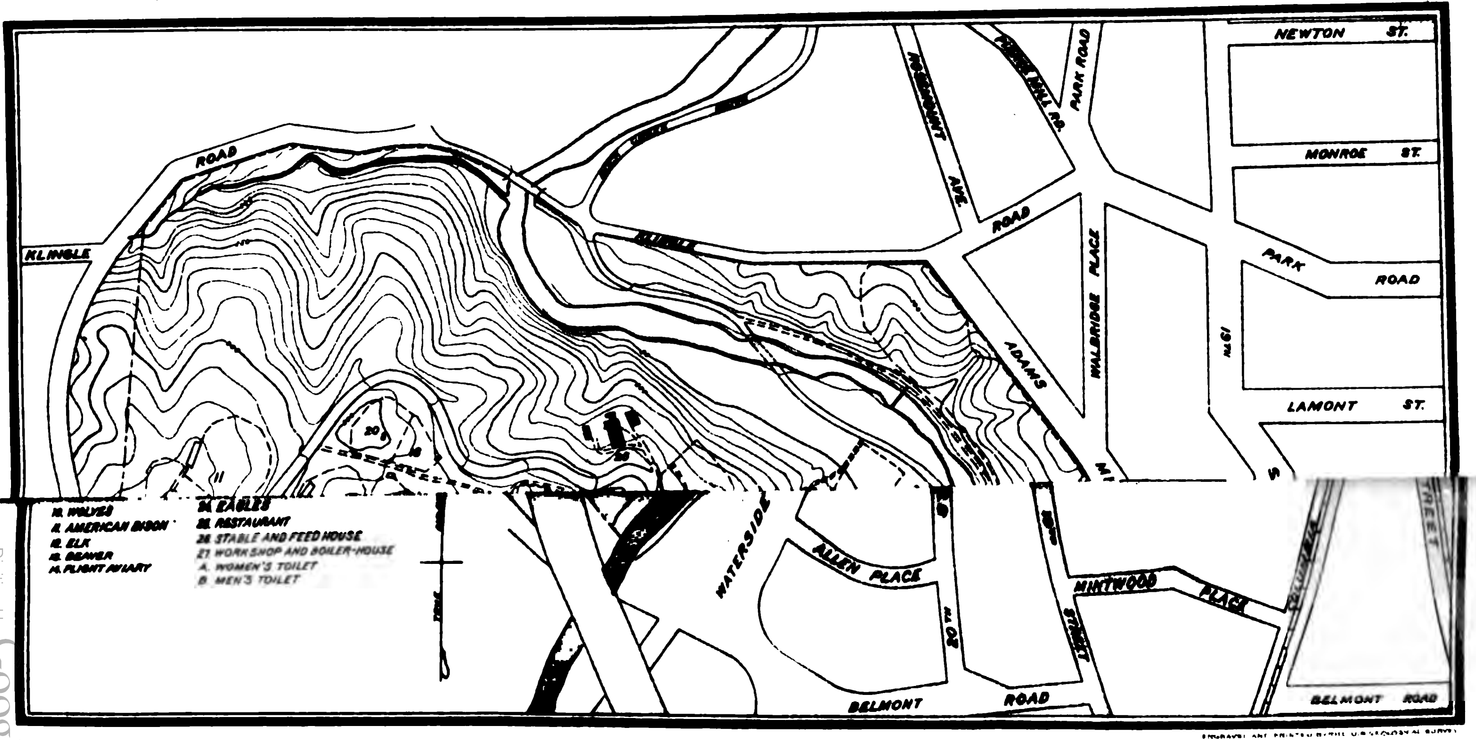
A time comes when, after an answer to a supreme shock, there is a sudden end of the plant's power to give any further response. This supreme shock is the shock of death. Even in this crisis there is no immediate change in the placid appearance of the plant. Drooping and withering are events that occur long after death itself. How does the plant, then, give this last answer? In man, at the critical moment, a spasm passes through the whole body, and similarly in the plant I find that a great contractile spasm takes place. This is accompanied by an electrical spasm also. In the script of the death recorder the line, that up to this point was being drawn, becomes suddenly reversed and then ends. This is the last answer of the plant.

These, our mute companions, silently growing beside our door, have now told us the tale of their life tremulousness and their death spasm in script that is as inarticulate as they. May it not be said that this, their story, has a pathos of its own beyond any that we have conceived?

We have now before our mind's eye the whole organism of the perceiving, throbbing, and responding plant, a complex unity and not a congeries of unrelated parts. The barriers which separated kindred phenomena in the plant and animal are now thrown down. Thus community throughout the great ocean of life is seen to outweigh apparent dissimilarity. Diversity is swallowed up in unity.

In realizing this, is our sense of final mystery of things deepened or lessened? Is our sense of wonder diminished when we realize in the infinite expanse of life that is silent and voiceless the foreshadowings of more wonderful complexities? Is it not rather that science evokes in us a deeper sense of awe? Does not each of her new advances gain for us a step in that stairway of rock which all must climb who desire to look from the mountain tops of the spirit upon the promised land of truth?

PLATE 1



ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

THE NATIONAL ZOOLOGICAL PARK AND ITS INHABITANTS.[1]

By Dr. FRANK BAKER,
Superintendent of National Zoological Park.

[With 41 plates.]

In the year 1890 Congress authorized the purchase of land for the establishment of a national zoological park, to be placed under the direction of the Smithsonian Institution.

The site, about 167 acres in extent, was selected with much care and is very beautiful. From north to south, a distance of more than three-quarters of a mile, it is traversed by Rock Creek, a streamlet that winds through a valley inclosed by steep, tree-clad hills and cliffs of gray, moss-covered stone. At that time fewer than a dozen houses bordered upon it, and it was thought that its seclusion was complete. Even now, when by the growth of 20 years the city has nearly surrounded it, the shut-in valley, with its woods and stream, lies quiet and remote.

The act establishing the park declared it to be for the "instruction and recreation of the people," and every effort is made to meet this requirement. Thousands of children make it their happiest playground. Babies dig in the sandboxes or sleep in the shade of the great trees; small boys and girls wade in the creek and scramble over the rocks; older ones play ball on the lawns in summer and skate on the ponds in winter; and all ages picnic by the tables or in the pleasant shade of the woods. Schools come in bodies to pursue their nature studies, and pupils training for teachers study the wild birds, the trees, shrubs, and animals.

The National Zoological Park is a favorite resort for the pastime of egg-rolling on Easter Monday, as it has many extended slopes down which the eggs can roll and the children run until they are tired. The accompanying illustration (pl. 2), shows the appearance of the lion-house hill upon such a day, yet gives but a slight idea of the great crowds of children present. In order to find out the actual number of visitors, watchmen were stationed at each entrance on this day to record the persons passing in on foot and in carriages.

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[1] Reprinted by permission from the Volta Review, Washington, D. C., July, 1912, and September, 1914.

The total number for Easter Monday, 1914, was found to exceed 57,000.

The main buildings are grouped within a comparatively small area. The most important is the lion house, shown in the background of plate 2. This contains most of the large cats, as well as a number of other interesting animals. Behind it are the monkey house, the bird house, the antelope house, each well filled with animals; at the west of these are the main inclosures for bears. In the valley below are the wolves, foxes, and dogs, the sea-lion pool, the beaver pool, the inclosures for otter, etc., and a shady pathway leads to the western entrance to the park. Along this pathway are various cages and inclosures. The houses for the elephants are along the main road beyond the antelope house. These houses and paddocks do not comprise the whole collection, for against the cliff at the very southern side of the park are another set of bear dens and an inclosure for the chamois; on the eastern side of Rock Creek are paddocks for elk, on the western side those for llamas, yak, and camels.

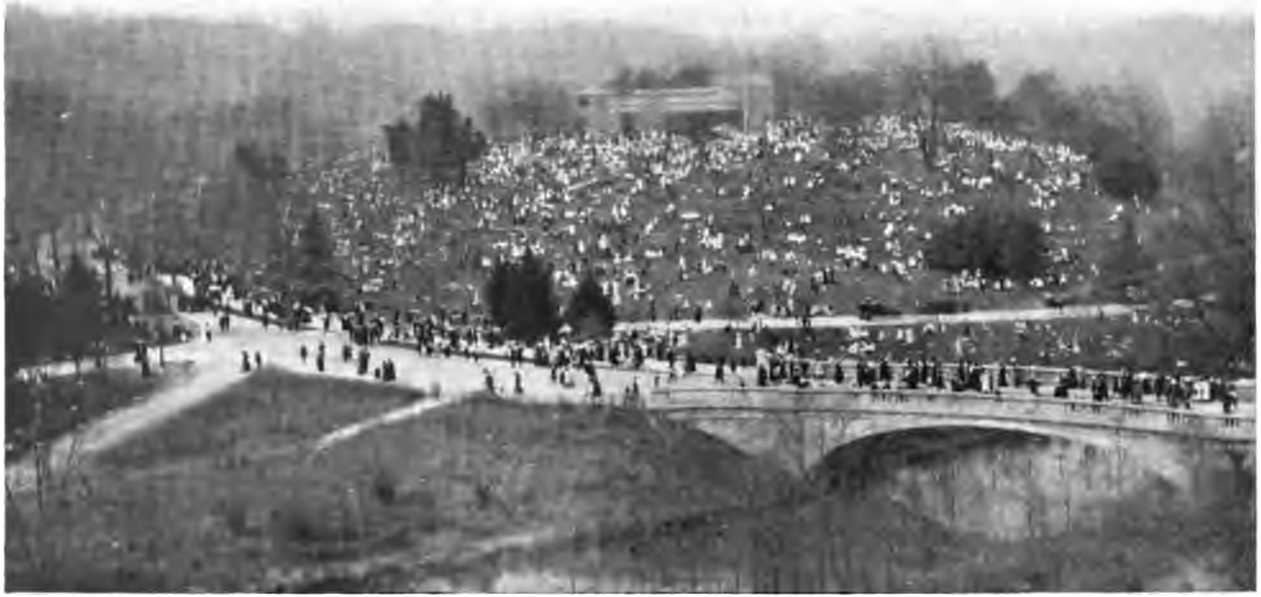
Along the main pathways are cages containing animals so inured to changes of climate that they can remain out all winter.

A flock of wild turkeys, several coveys of partridges, many peacocks, squirrels, and wild rabbits make their homes here and wander in perfect freedom throughout the whole extent of the park. At the opening of spring of 1913 a flock of wild geese voluntarily came down and settled in the pond where the other geese are kept. These beautiful birds became quite tame but unfortunately again took flight.

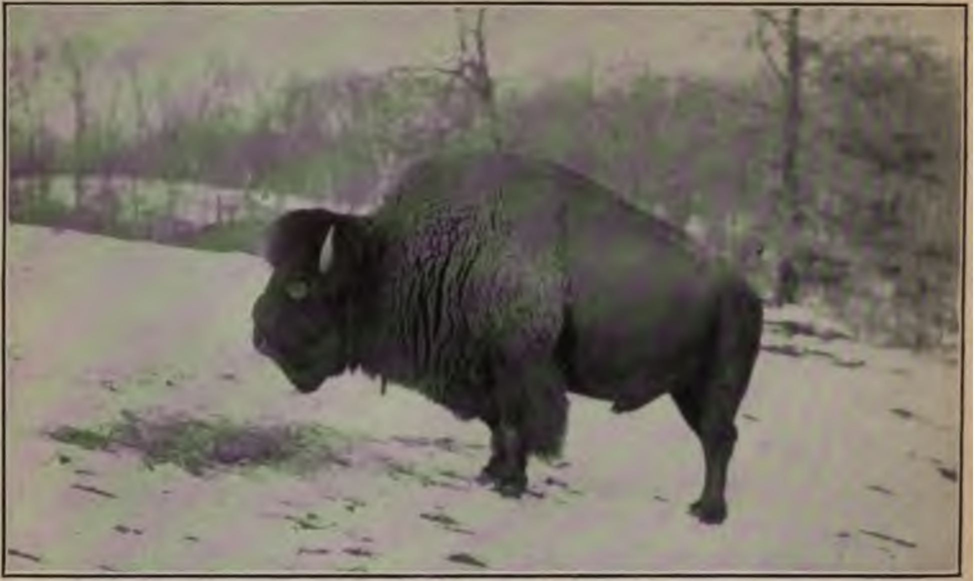
THE AMERICAN BISON. THE YAK.

When the park was first established it was thought that one of its principal functions should be the preservation of races of animals about to become extinct, and one of its earliest cares was the collection of a group of American bison, the great grazing animal that only 40 years ago roamed in vast herds on the plains of the Middle West and was rapidly disappearing before the advance of railroads and the rapacity of hunters. The project for the preservation of this interesting and valuable animal has proceeded, chiefly under the stimulus of Dr. W. T. Hornaday, until at present there is no reason to suppose that it will wholly disappear, there being several large parks established where it breeds freely. A careful census made by the American Bison Society shows that there were in North America, January 1, 1914, 3,788 bison, of which 3,212 were in captivity, and that they are slowly increasing in numbers.

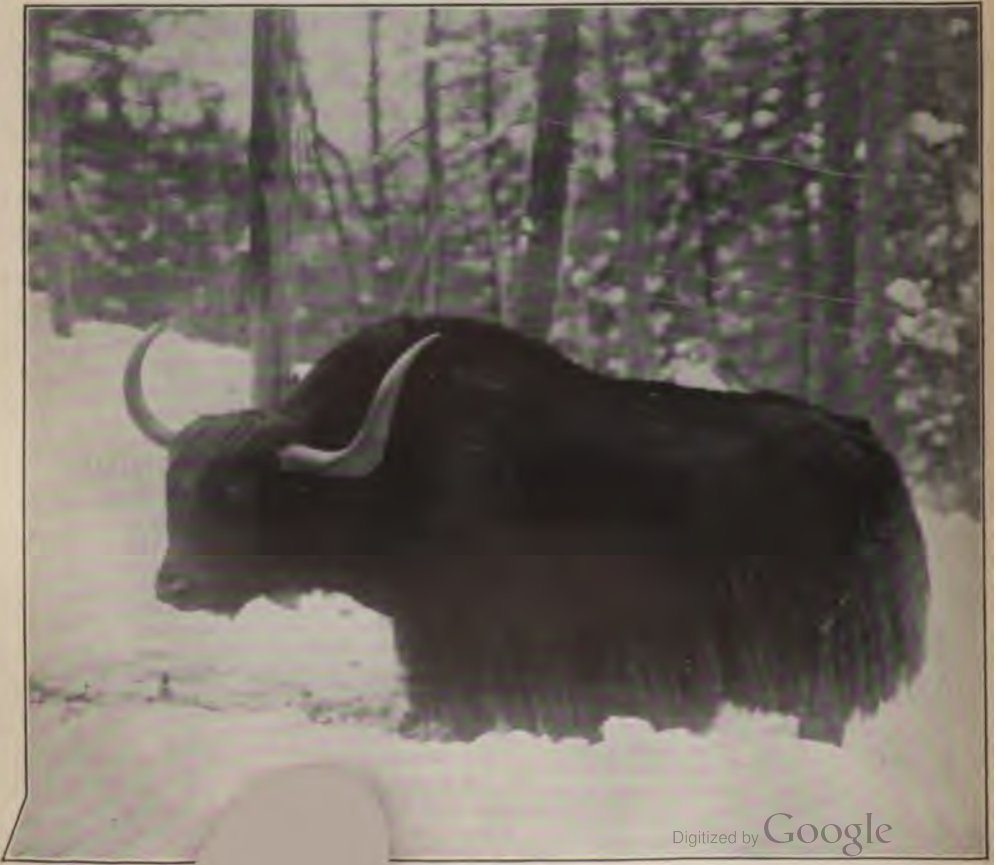
The early settlers in America, with that strange mischance that seems to preside over the naming of new animals, called the American



THE NATIONAL ZOOLOGICAL PARK. THE LION-HOUSE HILL ON EASTER MONDAY.



AMERICAN BISON.



THE YAK.

bison a "buffalo," a name which properly belongs to a quite different group. The genus Bison is common to both Europe and America. The European animal once pervaded the great forests of Germany, Austria, and Poland very much as our form did the western plains, but retired before advancing civilization, until now it is found only in two carefully guarded preserves, in central Russia and the Caucasus. He is not as picturesque an animal as his American cousin.

The immense head and shoulders of the bison give it an aspect of great force and dignity, and it is a favorite subject with sculptors and painters. I am informed by Mr. Charles R. Knight, the well-known illustrator, that the bison engraved on the United States treasury note for $10 was from a drawing made by him of the very animal shown in plate 3. As is the case with many herding animals, there is usually a single one who by superior strength and prowess commands the others and becomes the leader of the herd. In the course of time his powers weaken and some younger aspirant displaces him. A tragical occurrence of this kind happened at the park a few years ago, when two young bulls attacked the reigning monarch of the herd and gored him to death in spite of the exertions of the keepers. The short, powerful horns of the animal can inflict serious injury, and it is not safe to approach too closely the fence of the paddock where they are confined. They have been known to attack and seriously injure their keepers.

The yak, an animal nearly allied to our bison, is found in quite a distant part of the globe, in the high, mountainous regions of Tibet Its heavy, thick coat of hair, which falls about it in long fringes nearly to the ground, shows that it is prepared to resist extreme cold. This hair is so arranged as to form a kind of mat for the animal when it lies down upon the icy rocks where it makes its home. The legs are short and stout and the hoofs large and rounded, well calculated to give it a footing upon the mountain passes. Its horns are wide and spreading, somewhat like those of some varieties of our domestic oxen. The specimen shown in plate 3 used to delight in digging up the earth with these great horns, defacing the hillside of its paddock so that he had to be removed to more level ground.

Adapted to resist cold, this animal is rather intolerant of heat and suffers considerably during the heated term of a Washington summer. It does not bellow like our oxen, but has a rather characteristic grunting bark, which has led to its being called the grunting ox.

The yak has been domesticated and is used to carry burdens over the mountain passes of upper Tibet. It is said that without them traffic would be almost impossible, as there are no other animals that can be used there. The domesticated variety is almost invariably white, while the wild ones are usually dark colored, like the specimens in the park.

The cows of this species are smaller than the bulls. They are usually horned, but it is not uncommon to see animals that are "polled," or hornless. Young have been born in the park from the pair that was there for several years, and several of these are without horns.

This group of oxlike animals should not be left without noting that there are to be found in the park several others quite distinctive and important. The first of these is the true buffalo, from East Africa, a young animal of powerful build, whose horns and bodily frame are quite different from those of our bison. The second is the little anoa, or buffalo, from the Celebes, the smallest of the ox tribe, not larger than a small Shetland pony. Both of these are in the antelope house. There is also, in a separate building, a group of zebus, or humped Indian cattle.

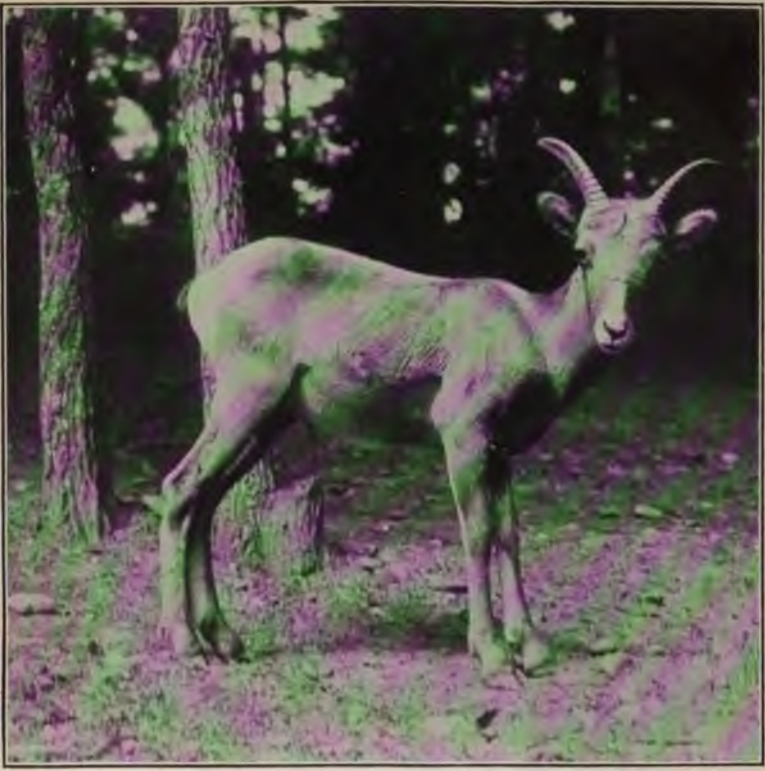
MOUNTAIN SHEEP.

This noted American animal inhabits the most lofty and desolate regions. It is not accustomed to the more humid and heavy air of the Atlantic seaboard and does not thrive well when confined here. When first caught it is exceedingly timid and liable to die from what might be called in a human being "home-sickness," as it pines and refuses to eat. The only way of succeeding with these animals is to capture them when quite young and furnish them with a foster mother, like a goat or domestic sheep. The specimen shown in plate 4 is a young male that was in the park for some time. The adult male has much larger horns and is a very fine and imposing animal.

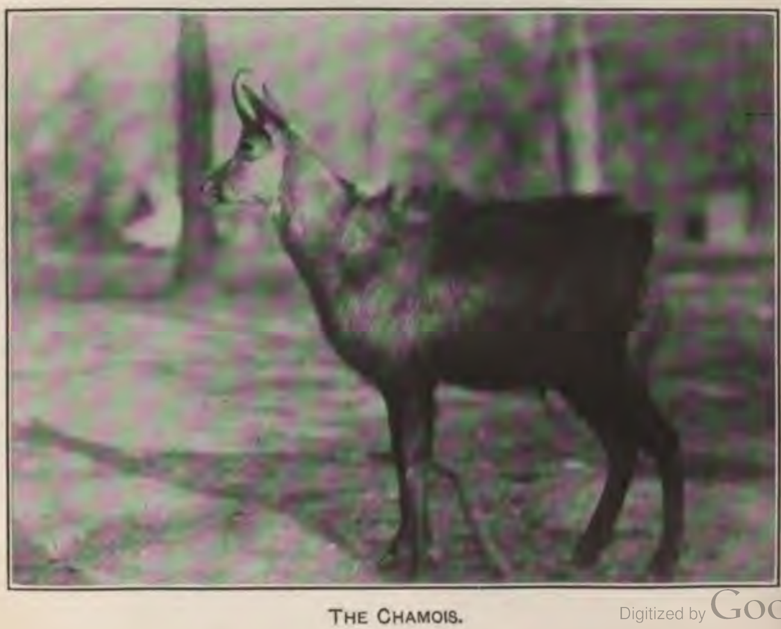
Several specimens of a near relative of our mountain sheep may be seen. These are the Barbary sheep from the Atlas Mountains of Africa. The male of this animal possesses when fully grown a mane of long hair covering its chest and forelegs. Its horns are large and powerful, but do not reach the size of those of our own sheep. The color of the animal is like that of the rocks of their mountains, a reddish yellow, and, as their instinct leads them to remain perfectly quiet upon the approach of man, they are very difficult for the hunter to discover.

The woolless sheep from the Barbados is also here.

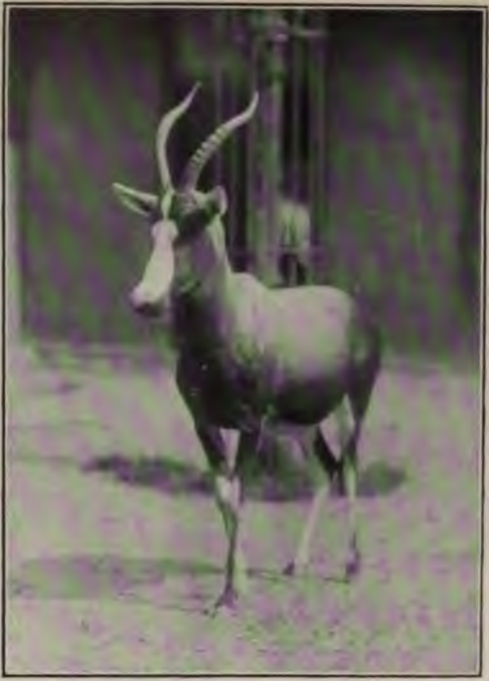
Through the kindness of the Swiss Government the park has been enabled to exhibit specimens of the chamois, or wild goat of the Alps. They are located on the steep cliff at the southern boundary of the park, a situation not very dissimilar to that which they occupy when at home. They are very agile and surefooted, and can leap from



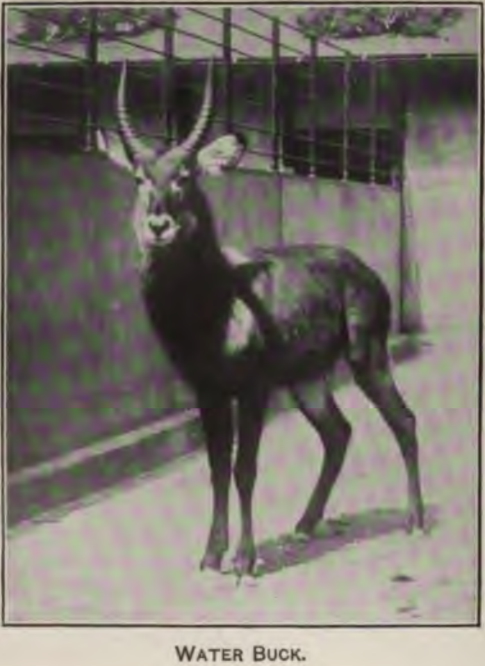
BIGHORN, OR AMERICAN MOUNTAIN SHEEP.



THE CHAMOIS.



BONTEBOK.



WATER BUCK.

rock to rock with the greatest ease and obtain a foothold on a pinnacle that scarcely seems large enough to hold their feet. Their hook-like horns are very sharp and dangerous. They thrive well here, as they have bred and raised young.

The park has also specimens of the tahr, an Asiatic mountain goat from the Himalayas. These look like our domestic goat, but have no beard. Their horns are black, the general color of their hair dark brown. They live on extremely precipitous cliffs. These animals have bred in the park and seem to endure captivity well.

ANTELOPES.

Notwithstanding the advance of European settlement, Africa still exhibits a remarkable variety of wild game. Antelopes in great numbers and of great variety of form and size, together with giraffes and zebras, still roam over its vast grassy plains. The park is fortunate in having a number of specimens of this teeming animal life, but only a few will be mentioned.

The bontebok (pl. 5), was formerly very numerous in South Africa but has been nearly exterminated by hunters, only a few small groups remaining. It derives its name, given it by the Dutch colonists (pied goat, when translated), from the marked contrast between the white coloring of its face and rump and the brown or fawn color of its body. Its horns are black. The blessbok (blazed goat) is another rare animal of quite similar character.

There is a pair of Coke's hartebeests, a rare species inhabiting eastern Africa, having widely expanded horns capable of inflicting a dangerous blow.

The waterbuck (pl. 5), or defassa, from the same region, lives among the high grass of swampy regions and is also found on higher ground, fleeing to the valleys when pursued. It is reddish brown in color.

The white-tailed gnu is the animal often styled the horned horse. The Dutch call it the "wildebeest," as if it were a wild form of domestic cattle. The specimen in the antelope house is very fond of dancing and curveting about his inclosure, uttering sharp barking cries.

The harnessed antelope is from western Africa and is another water-frequenting animal. It receives its name from the peculiar narrow white markings, that make it appear as though wearing a harness. It has hoofs especially adapted for walking on swampy ground.

An animal related in its structural formation, though much larger, is the nilghai from India. It lives in small groups on grassy plains or among thin brushwood.

The largest of all the antelopes is, however, the African eland, which formerly ranged over a large extent of country, but is now confined to central and eastern Africa. It is quite oxlike in its appearance, its flesh is excellent eating, it is said to be easily domesticated and might be made of use as a draught animal.

The small antelopes known as gazelles are noted for their delicate symmetry and graceful movements. The animal shown in plate 6 is from the plains of East Africa, where it is found in great numbers. The male has very long horns, which are ringed from the base nearly to the tip.

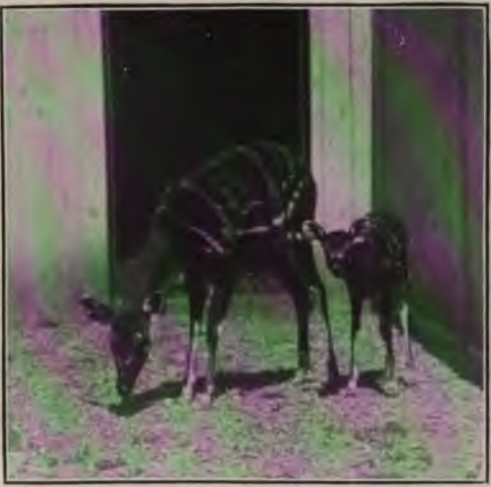
Gazelles are remarkable for their speed, being among the swiftest of the antelope tribe. Consequently they are so lean and sinewy that their flesh is not very good eating. Their colors are excellently adapted to conceal them, being almost exactly the same shades as are seen on the dry plains or sandy deserts where they have their home. It is from their skins that are made the water sacks that are commonly used in the East for the transportation of water.

The springbok is another most beautiful member of this group, cinnamon colored upon the back, snowy white below and upon the rump, where it has a patch of long white hair which it can spread when excited. It receives its name from the peculiarity of its gambols, during which it leaps suddenly upward, sometimes quite over the backs of its fellows in the same herd, as if engaged in a game of leapfrog, doing this with the utmost ease, without perceptible exertion. This animal was formerly very numerous in South Africa, and is still found there in considerable numbers, occasionally, when driven out by drought, pouring down from the interior toward the settlements in immense migratory herds, and laying waste the cultivated regions.

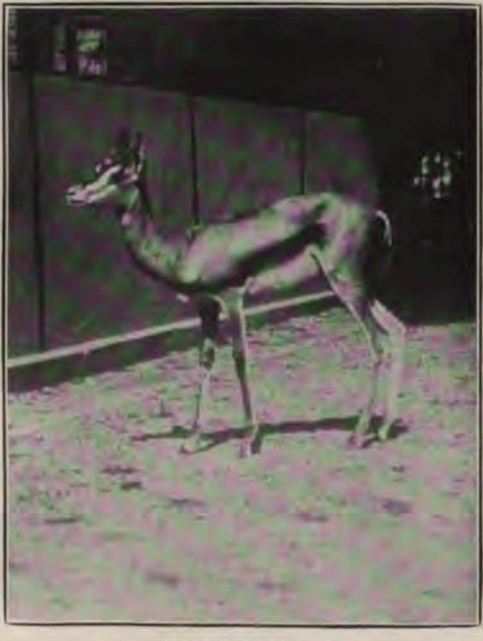
The Indian gazelle, or black buck, is also a plains animal but confined to the continent of India. The male only is entitled to the name, being, when full grown, of a deep, glossy black above and a snowy white below, the female being cinnamon brown above and white below. The horns of this animal are long and peculiarly shaped, being not only ringed but spirally twisted, like those of the fabulous unicorn, which has led some to suppose that this animal may in some obscure way have given rise to the conception of that mythological beast.

This is one of the animals that is hunted by means of the cheetah, or hunting leopard. Though very fleet of foot, it can not equal the speed of this swiftest of the cat tribe. It breeds readily in captivity and several young have been born in the park.

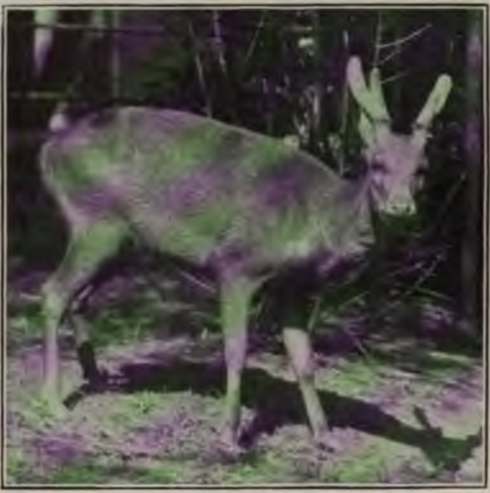
America has but one species that can be placed among the antelopes, and that is of a very peculiar type. The old-world antelopes differ from the deer family in not shedding their horns annually, but retaining them throughout life. Our own antelope, the prong horn (pl. 7), agrees with the deer in shedding its horns, but conforms to the African and Asiatic species in general appearance and habits. It was



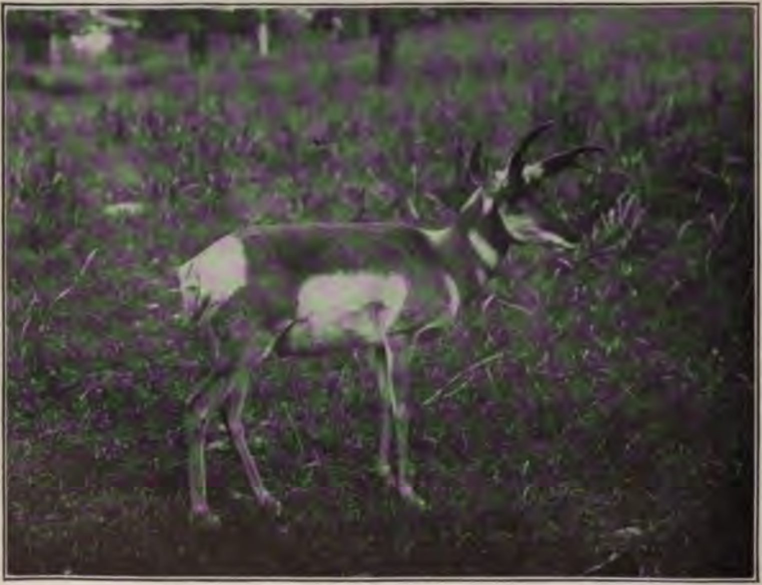
HARNESSED ANTELOPES.



GRANT'S GAZELLE.



PHILIPPINE DEER.



PRONG-HORN ANTELOPE.

formerly common throughout the plains west of the Mississippi, but its range is now much less. In the Yellowstone Park, where it is carefully preserved, a considerable number are found. It does not stand well the more humid climate of the eastern United States, and on this account is difficult to keep in zoological collections. It is easily tamed and becomes very familiar with its keepers.

THE DEER.

The deer family is a very large one, comprising specimens inhabiting every quarter of the globe. The most striking characteristic of the race is the almost universal possession by the males of peculiar branched appendages termed antlers, or horns, which are cast off every year and again renewed with astonishing rapidity. The park possesses specimens of many different species of this family.

Of distinctively American species, the Virginia deer is the most famous as well as the most widely distributed. It still lingers in the forest of the northern United States, in the Alleghanies, and in the South, extending into Mexico. It varies much in size and color in different localities. A fine specimen is a most beautiful object, as may be seen by the picture of a fawn in plate 8. This photograph was taken in the Blue Mountain Forest Park, and is published by the kind permission accorded by Mr. Baynes, one of the board of managers of the Bison Society. Similar animals are shown in the National Zoological Park, but this illustration is presented because it is an unusually successful photograph, not always easy to secure in the case of living animals.

Notwithstanding their apparent gentleness, the bucks of this species are at times very dangerous animals. On one occasion a buck attacked the principal keeper at the park and would probably have killed him if he had not been able to get behind a tree and, by seizing both antlers, hold the animal until assistance could arrive. It is often necessary to saw off the antlers from ugly bucks to prevent their injuring others.

Specimens of the mule deer, a western form with large ears, may also be seen. This species was formerly very abundant on the western plains. Care is taken to preserve it in the Yellowstone National Park. One of these animals once jumped over the 8-foot fence of its paddock and created considerable excitement by wandering about the city. After a few days it came back to its paddock and submitted again to being shut up.

Our largest American deer is the moose, known in Europe as the elk, a term which we have improperly applied to the wapiti. Several attempts have been made at the park to keep the moose, but these have not been very successful. The animal lives in the vast northern forests and feeds almost wholly upon the young twigs of trees or upon pond-lily roots, and suitable food is therefore very difficult to procure.

The wapiti or elk, on the contrary, seems to thrive well in confinement, eating hay and grass like a domestic animal and breeding freely. On the eastern side of the park is a large paddock where a number of these stately animals can be seen. The wapiti was formerly very abundant in nearly all parts of North America, but its range is now greatly restricted. There are still considerable herds in the Yellowstone Park and in the Olympic Mountains of the western coast. At the approach of autumn the peculiar melodious call of the stags can often be heard.

There is also a small band of the European red deer, nearly related to the wapiti, although considerably smaller in size. These are the deer so famous in song and story, still found wild in the Scottish highlands and eastern Europe and preserved in many English parks.

The fallow deer is another species widely preserved in England, though it is a native of the Mediterranean countries. It is yellowish brown in color, marked with white spots.

Closely allied species represented in the park are the axis deer of India, the Japanese or sika deer, and the swamp or barasingha deer, also of India.

An interesting example of another group was presented to the park by the late Admiral R. D. Evans, United States Navy. This animal is from the Philippine Islands. It is quite small, and probably lives in an alluvial country, as it delights in plowing up the earth with its antlers, and is usually covered with mud that it gets from digging in its yard.

The sambar deer of eastern Asia is a larger representative of this group, and the little hog deer is a smaller one, not being larger than a pig of medium size.

The barking deer, or muntjac, of the same region is also represented. This animal is of a deep chestnut brown and has antlers of a very simple pattern, resembling somewhat those of the pronghorn antelope.

The park has also a specimen of the famous reindeer, used by the Laplanders as a draft animal. It has to be fed entirely upon moss and lichens brought from the north, as it never gets accustomed to eating hay.

THE CAMEL.

The strangest beast of burden is the camel of the old world, a long-legged, ungainly animal, vicious in temper and ugly beyond description. In both Asia and Africa it is domesticated. The camel of Africa and Arabia, often called the dromedary, is distinguished by one hump, while the central Asiatic or Bactrian camel has two.

VIRGINIA DEER.

THE LLAMA.

F[illegible] HE BABY BACTRIAN CAMEL, ONLY 1 DAY OLD.

Both have a peculiar series of cavities in the lining of the stomach, by means of which they retain from a gallon to a gallon and a half of water separate from the food; this enables them to go many days in the hottest climates without drinking, a peculiarity which makes this beast invaluable in the desert. The humps upon the back are another provision of nature by means of which the animal is assured of sustenance, being made up principally of lumps of fat that increase in size when the animal is well fed, and on which he draws when there is little or nothing to eat. The feet of the camel are very peculiar, being large, spongy pads adapted for traveling over sand. The small camel in plate 9 is of the Bactrian variety, and was born in the park. Biting and kicking him when he tried to nurse, his unnatural mother would have nothing to do with him, and it was necessary to put him in a separate yard and to bring him up by hand. The picture shows him when but 1 day old, nursing from a bottle held by the keeper.

The Arabian camel exists in a wild state in Spain, and the Bactrian is found wild in certain parts of central Asia, but these have doubtless descended from animals that have escaped from domestication. Both species are exceedingly stupid animals, sometimes very ill-tempered and dangerous, inflicting savage bites with their powerful canine teeth.

THE LLAMAS.

In South America are found four representatives of a genus allied to the camel. These are the llama, the alpaca, the vicugna, and the guanaco. The first two are domesticated and the others wild. Specimens of each are owned by the park. These animals have a long neck, a large head, and long ears like the camel; but, as they have not the hump, they are much more graceful.

All of these species live in temperate climates, usually upon the higher slopes of the Andes, but coming down to sea level in Patagonia. They do not thrive in humid regions and attempts to utilize them in other countries have usually failed.

They all have the very unpleasant habit of spitting at visitors that stop to examine or pat them.

The guanaco is now believed to be the true ancestor of these several stocks. It is found in considerable flocks on the higher mountains from Ecuador to Tierra del Fuego, and is very wild and wary. It is said that when about to die it seeks a spot commonly resorted to by the flock for a place of demise.

The vicugna is smaller than the guanaco and is much more restricted in its range, being confined to Peru and Bolivia. Formerly the wild vicugnas and guanacos were rounded up annually by great numbers of Indians, then carefully sheared, and allowed to escape. From the wool thus obtained a fine and durable cloth was manufactured. The finest was made from the wool of the vicugna, which was therefore reserved for the use of the Peruvian nobles. At the present day this is rarely used, being difficult to obtain since the periodical hunts have been abandoned. Instead of this the wool of the domesticated alpaca is employed and has become a valuable article of export for producing the well-known cloth of the same name.

When the Spaniards came to South America they found the Peruvians in possession of vast herds of llamas, which they used principally for burden bearers. Large troops, 500 or even 1,000 in number, transported merchandise by scaling the difficult mountain passes of the Andes. Horses and mules have gradually displaced the llama as a beast of burden, and these large caravans are no longer seen. The llama is still used as a burden bearer, but can carry only 100 pounds or so at a time, so that great numbers are required when there is much to transport. Both the domesticated and the wild animals live by grazing, and in captivity are fed on hay like domestic cattle.

THE ZEBRAS.

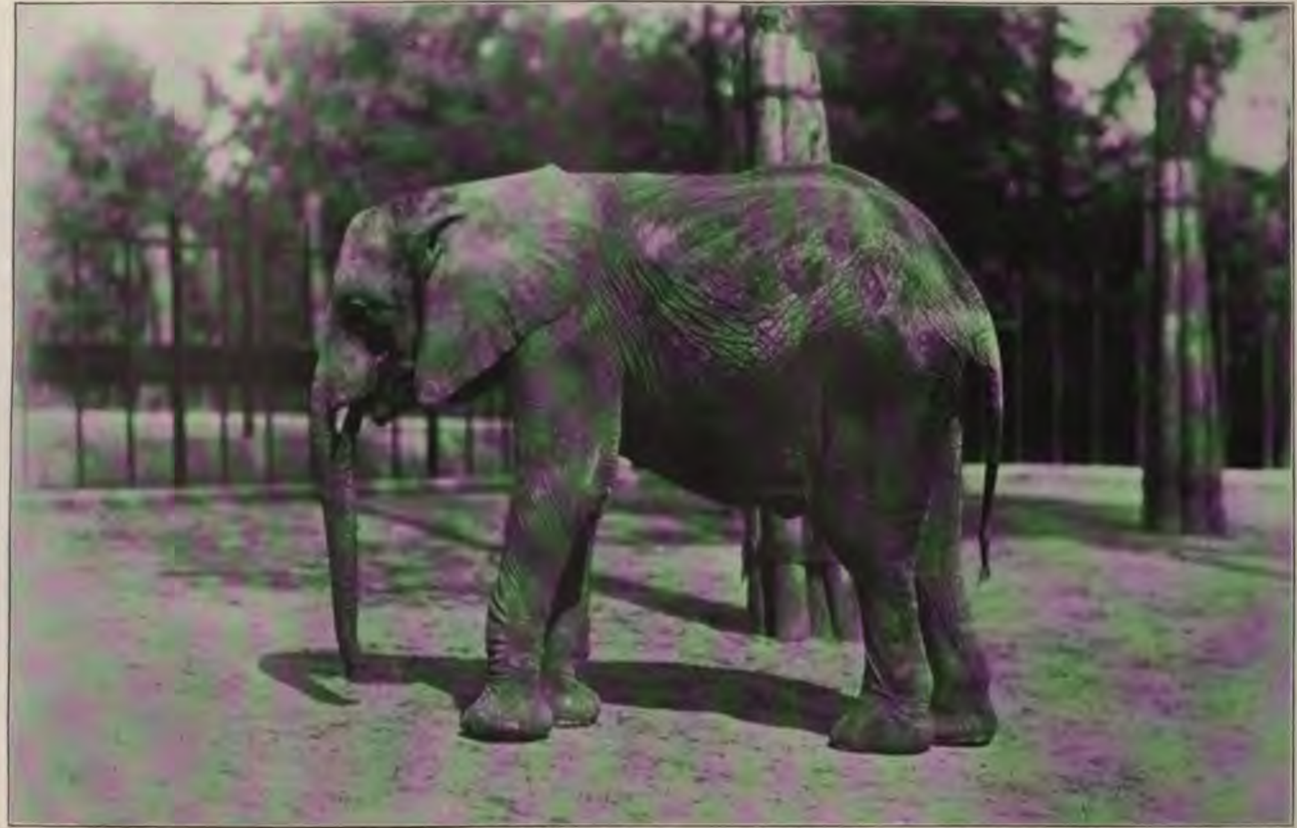
Among the horselike animals the zebra is one of the most interesting. It is an African animal, once existing in vast numbers from Cape Colony in the south to Nubia in the north. Its peculiar striped markings make it a striking object, and it was early sought as suitable for menageries. The earliest ones exhibited were from South Africa, and were of the form known as the mountain zebra. They have become rare and are now carefully preserved by the British Government. Two other species exist, both of which are represented in the park. The finest of these, the Grevy zebra, shown in the picture (pl. 10), was sent from Abyssinia by King Menelek as a gift to President Roosevelt. It appears to be a favorite selection for a royal gift, as the King also sent a pair to Queen Victoria and another to President Grevy of the French Republic, whose name was promptly used by the French naturalists to designate the species. Formerly it was rarely seen, though it is found in great abundance in Abyssinia and British East Africa. Since the construction of the railroad from the coast to Nairobi has opened up this country, a considerable number of animals formerly but little known have been brought to Europe. This zebra is more delicately striped than the other species and is also much larger, the animal at the park being equal in size to a small horse. Successful attempts have been made by the Department of Agriculture to breed this animal with the domestic ass. One of the hybrids from this union is on exhibition at the park.

The other variety of zebra on exhibition is a subspecies of the Burchell zebra, known as Grant's zebra. It is a smaller animal with broader stripes. It also is found in abundance in the region about Mount Kilimanjaro.

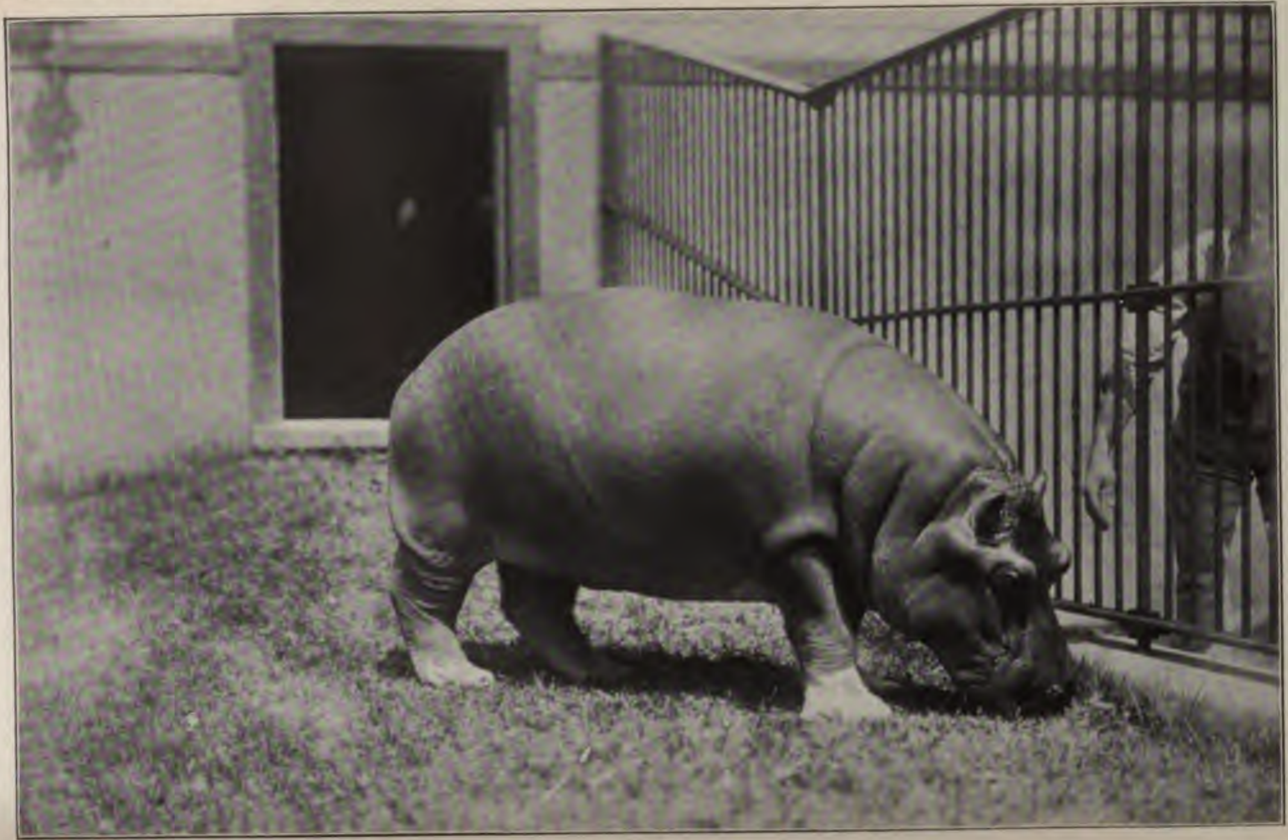
GREVY ZEBRA.

YOUNG TAPIR.

ASIATIC ELEPHANT.



AFRICAN ELEPHANT.



HIPPOPOTAMUS.

THE PACHYDERMS.

The park is fortunate in having a number of the large, thick-skinned animals known to naturalists as pachyderms. There are at present three elephants, two hippopotami, four tapirs, and a number of swine of different species in the collection.

The elephant is the largest animal that lives upon land. He grows to 10 feet or more in height and may weigh many thousand pounds. The one in the park is 9 feet 1 inch high at the highest point of his back and weighs about 11,000 pounds.

Elephants have huge feet and thick, dark-gray skin that hangs in loose folds and is covered with short, scanty hair. Their large and massive heads have great flapping ears and small eyes. Their most remarkable feature is a long proboscis, or trunk, formed by the union and excessive growth of the upper lip and the nose. Through it the elephant breathes and smells; with it puts food and drink into his mouth, throws dirt or hay on his back to protect it from flies, pulls down trees, lifts heavy burdens, or safely picks up the most delicate and fragile things. It is most sensitive to touch and serves the purpose of a hand. With it the beast can untie knots, open doors, or give himself a shower bath.

There are at least two groups, the elephants of Africa and those of Asia, and varieties are often known by the name of the country they inhabit, as the Indian elephant of India and the Ceylon elephant of Ceylon. The latter variety is often without tusks, and it therefore appears probable that the one at the park is from Ceylon.

They are hunted for their hides and their tusks of ivory, and, particularly in Asia, are sometimes caught and trained for use. While usually gentle, they are not easily trained, being really stupid, although seemingly intelligent. It is a curious fact that, although so large and powerful, the elephant is timid and easily frightened, being quite afraid of a mouse or of a small dog.

The Asiatic elephant of the park has a house to himself, where, behind the heavy bars that shut him from the public, he is free to move about, to go out into his large inclosure, and to take a bath in his big tank, as shown in plate 11. He is fed on the best of hay, of which he eats 125 pounds each day, and he stretches his trunk out to visitors for other food; but, because he was once made dangerously ill by eating several bushels of peanuts thrown to him on a crowded day, visitors are no longer allowed to feed him.

The African elephant (pl. 12) is represented by two young specimens, male and female, about 5½ and 4 years old, which were received from the Giza Zoological Garden. They were captured in Abyssinia, near the Blue Nile. They were named Jumbo, jr., and Jumbina, in memory of their great predecessor Jumbo, who was probably the largest elephant ever seen in captivity. They differ notably from the Asiatic species both in the shape of the body and the enormous triangular ears which overlap each other on top of the neck when at rest but stand out at right angles when the animal is excited. The males reach greater size than the Asiatic, occasionally exceeding 11 feet, and have very large and heavy valuable tusks, which have caused them to be gradually killed off in the more accessible regions. The animal is now protected by governmental regulations. Its hunting is by no means free from danger, and in this respect it ranks with the lion and buffalo. While its sight is not very good, it has a very keen sense of smell. Naturalists consider that there are several species and varieties in Africa. In modern times it has not been reduced to servitude like the Asiatic species, but it is supposed that the war elephants used by the Carthaginians were African.

The park has both a male and a female hippopotamus captured in East Africa. This most characteristic and striking of the animals of African rivers lives mostly on coarse herbage and water plants, but often ravages the crops of the natives, doing great damage, as it is an enormous eater and its stomach will easily hold 5 or 6 bushels. In captivity it is fed upon hay and various vegetables, with a little crushed oats, bran, and stale bread by way of delicacies, but hardly eats as much as would be expected from an animal of its size. When adult it may reach a weight of 4 tons. It thrives well in captivity and breeds regularly, so that many of the zoological collections of the world have been supplied from the offspring of captive hippopotami.

The tapirs also belong to the family of thick-skinned animals, or pachyderms. They have a short proboscis, small eyes, and short, thick legs. They are fond of standing or lying partially immersed in water. When wild they feed on roots, grasses, water plants, the leaves of certain trees, and sometimes on cultivated crops, to the inconvenience of planters. In captivity they are fed with ordinary garden vegetables. The adult tapir is of a dull, dark brown color, while the young are marked with gay stripes and spots of yellow and of white. They lose these markings after six months or so.

The little fellow shown in plate 10 is one of several born in the park. He was tame and good tempered.

THE GREAT CATS.

Within the lion house are, besides many other animals, a number of large cats, such as lions and tigers. The lion shown in plate 14 is one of five presented to the park by Mr. McMillan, of East Africa. These were caught when quite young cubs and reared by hand at Nairobi. They are distinguished by very heavy and powerful hindquarters, and are of a beautiful tawny color.

BENGAL TIGER.

KILIMANJARO LION.

TIGER IN BATH.

Such animals as this caused a great deal of trouble during the building of the railroad from Mombasa to Nairobi, frequently carrying off the native workmen, and even tearing open railway cars to get at their occupants.

A lion of quite a different type, slate colored and more slenderly built, was formerly owned by the park, being obtained from a woman in West Virginia who had reared it from birth by means of a feeding bottle. He was very tame and used to run about the house freely, but finally became too troublesome to be tolerated. Always very playful and tractable, he showed so much affection for his keeper that it inclined one to think that the old story of Androcles and the lion may not have been altogether fabulous.

He showed an unusual aptitude for training, allowing his trainer to handle him freely, apparently enjoying the exercise as a sort of play.

The lion once ranged over nearly the whole of the Eastern Continent, but in recent times is to be found only in Africa (in many parts of which he is quite exterminated) and in southern Asia.

The male is distinguished by a flowing mane and a brush of long hair at the end of the tail. His pose, with the head thrown up to keep his mane out of his eyes, is very commanding, and has gained for him the title of the "king of beasts," but the female, slinking stealthily along with her head lowered, has a less noble aspect.

There are no true lions in America, although the puma, or cougar, a wild animal that is found in parts of both North and South America, is often called the mountain lion. Conflicting stories are told of it. In the north it is said to be bloodthirsty and dangerous to man, while in the south it is disposed to be gentle and friendly. It lives upon flesh, killing wild animals and even birds in uninhabited regions, and, in times of scarcity, horses, cattle, and sheep are never safe in its vicinity.

The park has a beautiful puma which is very tame and likes to be petted. Its color is a warm gray. Other specimens are found of a yellowish or of a dark brown color.

The tiger is a native of Asia, abounding particularly in the jungles of India and the Malay Peninsula, but also extending northward into Korea, Manchuria, and the adjacent islands. Its appearance is not as noble and majestic as that of the lion, but its lithe and graceful movements and its sleek, shining coat, in color bright tawny striped with black above, and pure white below, gives it a kind of fearful beauty that the lion does not possess. Quite as large as the lion, the absence of mane makes the tiger appear smaller, and there is much controversy as to which animal is the stronger. There is no doubt as to its terrible power and bloodthirsty nature. During the torrid heat of the summer day it seeks the shade, coming out at night to hunt its prey. Tigers may live altogether upon wild game found in the forests or upon domestic cattle. It is estimated that at least 20,000 head of cattle are carried off by tigers in India during a single year. After becoming accustomed to cattle stealing and overcoming their natural fear of man, they not infrequently attack human beings. The man-eating tiger, as he is called, is the most terrible of beasts. He is crafty and moves so noiselessly in the darkness of the night that he has been known to snatch people from their beds without awakening neighboring sleepers. While not so numerous as formerly, tigers are still a scourge and a menace in many parts of Asia.

Tigers caught when very young may be tamed, but they can hardly be said to be ever safe as household pets. Any flesh-eating animal, even if reared in captivity and fed on milk, rice, and similar food, may seem to be quite tame and harmless; but if it gets the sight and smell of blood or bloody flesh, its innate instinct asserts itself and it becomes ferocious and is no longer to be trusted.

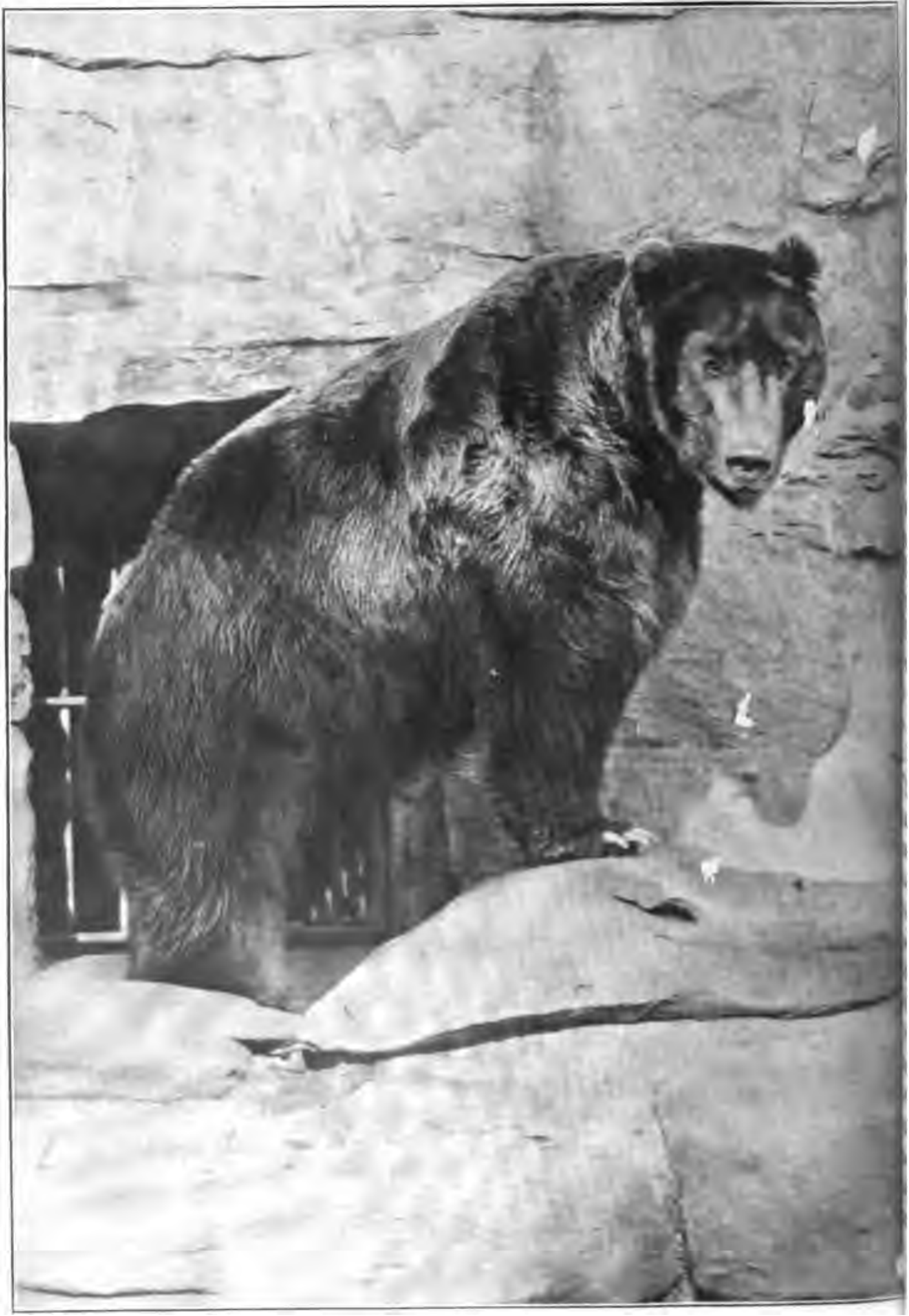
The animal shown in plate 15 is a large specimen, probably from Central India. On a hot day he was very fond of lazily immersing himself in a tank of water, very much as he would have done in his native jungle. The artist has caught him in the act of yawning. He was quite unmoved by the presence of visitors, and in order to show him at his best it was necessary to rouse him from his sleepy attitude.

The American jaguar is often called the tiger, or "tigre," by the natives of South and Central America. It resembles the leopard much more nearly, as it has the same general structure and a similar coloring, though its spots are larger and arranged in groups. It is much heavier than the leopard, and has enormously powerful jaws. It ranges from Patagonia to the northern boundary of Mexico, and has even been found in the United States.

It preys upon all wild life in its region—animals, fishes, and even birds—but rarely attacks man. In the southern forests it sometimes lives in trees, but it is found also on the treeless plains, showing considerable ability to accommodate itself to changes of climate, food, and general conditions.

Those who live in the country in Canada or along the Canadian border have doubtless heard of the "lucifee" (French loup cervier), or Canadian lynx, about which blood-curdling stories are told. The animal certainly has a most ferocious aspect and it is not strange that its weird, unearthly, screeching cry, its glaring eyes and erect hair, seen in the dusky wood, should frighten the casual passer-by and lead him to seek the shotgun kept for such emergencies behind the kitchen door. The early French settlers gave it the name of loup cervier (deer wolf) from its supposed habit of springing from trees upon the backs of deer and drinking their blood. These, however, are merely woodsmen's exaggerations, for the creature does not kill

AFRICAN LEOPARD.



ALASKAN BEAR.

anything bigger than a rabbit and never voluntarily attacks man. It is really rather timid, and its ferocious appearance is for effect rather than otherwise. It is found throughout British America and the northern border of the United States, and greatly resembles the European lynx that owes its name to its supposedly piercing vision. In the central or southern United States its place is occupied by the bay lynx, or "bobcat," of which there are several species at the park.

The leopard, or panther, is found both in Asia and in Africa, and is next in size to the lion and the tiger. From his stealthy habits he is more to be feared than either. He moves with marvelous agility, springing upward without apparent effort to a height of 6 or 7 feet, like a feather blown by the breeze. He runs as lightly as a squirrel up trees and lies along the branches, hidden by the foliage, through which his spots seem like the light and shade of the shifting leaves, and from his concealment drops upon his unsuspecting prey. Like all cats, he lives upon the flesh of other animals. Because of this he is a dreaded and hated scourge in the agricultural regions, where he devours the herds and flocks.

The leopard varies much in size and color. It is usually of a bright fawn, but may be black or, very rarely, white.

The distinctive characteristic of the leopard are the spots which cover the body and even the tail of the animal, of a darker color and often arranged in rosettes, shading from black on the outer edge to a light center. Even in the black leopard the shape of these spots can be discerned.

The park has a fine leopard, received from Aden, Arabia, a beautiful female presented by Mr. McMillan, and a black leopard of very ferocious aspect, seeming the very incarnation of devilish malignity.

Another specimen that may be seen is the serval, an African cat of quite a different aspect, having legs so long as to almost give it the appearance of walking upon stilts. It is of a light tawny color, with rather widely separated black spots. It has very much the same habits as its American cousin, the bay lynx.

Specimens of the very pretty spotted cats from Central and South America, known as the ocelots, may usually be seen at the park. They vary considerably in the pattern of their coloration, but have usually a ground color of warm gray on which blotches and stripes of black occur. When young they are as tame as young kittens and are quite as playful. One was kept for some time in the office of the park, running about the floor in complete liberty.

THE BEARS.

Bears are found in nearly every country in the world, from the frozen north, where the great white polar bear lives on the ice and snow, catching seals for food, to southern India, where the bear of the jungle hides in caves in the rocks, feeding on vegetables, fruits, and wild honey. Bears are of various colors—white, black, or brown, often with distinctive markings—but they all walk with apparent awkwardness, flat on the soles of their broad, heavy feet. The awkwardness is only apparent, however, for they can run with considerable rapidity, and some kinds can climb trees. The polar bears eat meat and fish, while others live chiefly on vegetables and fruits, occasionally eating fish or sheep, and in captivity are fed largely on bread. Bears are easily trained and often, when caught young and kindly cared for, are gentle and become fond of their keepers. The polar bear is the most stupid of all, while the jungle bear of India and the brown bear of eastern Europe are the most easily taught to dance, play tricks, and otherwise obey their trainers. All bears are very playful when young, and when alone or together tumble, turn somersaults, and run about for sheer love of exercise, like puppies or kittens. Most countries have bears that are not found elsewhere, but the brown bear is common to many lands. The real Americans are the black and grizzly bears. The black bear is still to be found in the deep woods, which he loves, hunting berries in summer and curling up for a nap of several months when winter comes and he can no longer find food. In captivity bears often remain awake and active all winter if they are regularly fed; but in the wild state they hibernate or sleep through the long, cold winter of the temperate and frigid zones.

The most ferocious of all bears is the grizzly. His great size and strength and the fact that he eats flesh make him feared by both beasts and men. Animals avoid his haunts, but men seek him, both for the sport of the hunt and to obtain the beautiful heavy pelt with its thick, grizzly gray fur. The grizzly is the only one of the bear tribe that attacks man unprovoked, and even he has been known to turn and walk away when met by a man who stood quietly, showing no fear and not offering to attack. He was long thought to be the largest of the bear species, but the Alaskan bear shown in plate 17 now disputes this claim with him. This specimen weighs 1,160 pounds, stands 51 inches high at the shoulders, and can take an apple from a stick held 9 feet 3 inches from the ground. He was brought to the park when a cub, and is now 11 years old. The size of his mother's skin was 11 feet 8 inches from tip to tip. The cub of the bear when born is very tiny, not much larger than a rat, and it does not open its eyes for 40 days, during which time the mother bear keeps it from all light.

A near relative of the bears is the frisky and mischievous little animal which we call the raccoon, but which the Germans call the

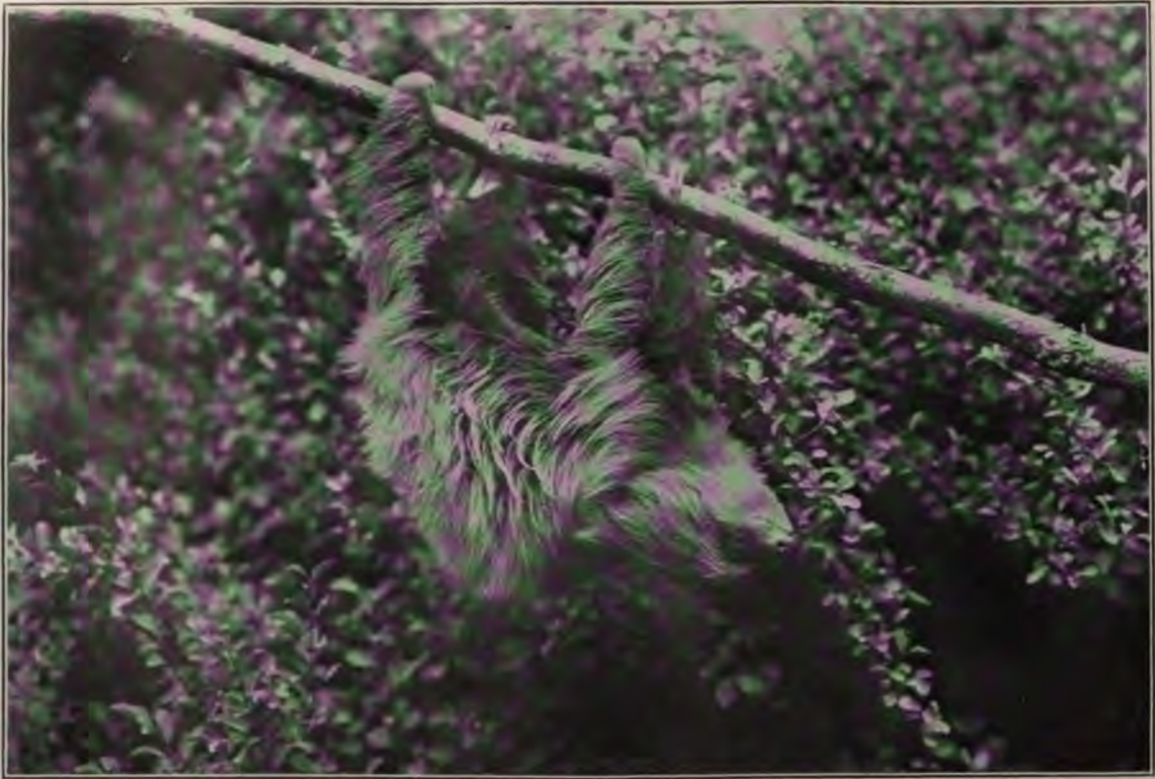
GRIZZLY BEAR.

POLAR BEARS.

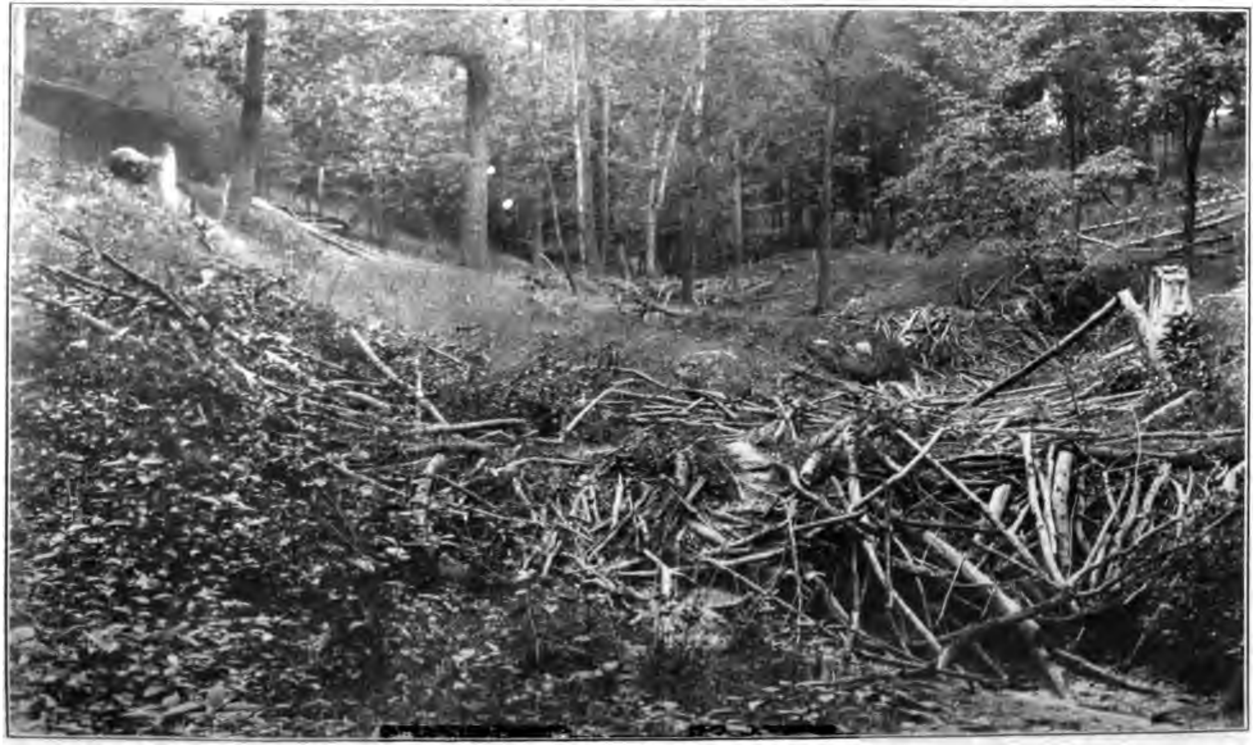
BLACK BEAR CUB.

RACCOON.

"NAPPER," THE MANDRILL.



TWO-TOED SLOTH.



WORK OF BEAVERS IN NATIONAL ZOOLOGICAL PARK.

waschbär, or washing bear, from its habit of paddling in the water and wetting its food before eating it. These creatures inhabited this region before the park was established, and their tracks are even now occasionally seen along the creek at the water's edge. A whole tree is devoted to them, where they may be seen hanging upon the limbs in various positions.

THE MONKEYS. THE SLOTH.

An entire house at the park is devoted to the monkey tribe, or primates. Nor is this any too large, for if the principal species only were exhibited, twice or three times the area would be required. The great manlike apes are at present lacking, though there was once a very interesting female orang on exhibition. Both Old World and New World monkeys are here—baboons from Africa and Arabia, the graceful Diana monkey from the western coast of Africa, macaques of various kinds, the thumbless spider monkeys, the capuchins and the "weepers" of South and Central America, besides lemurs from Madagascar. One of the most mischievous of this tribe is a young mandrill, whom the keepers have christened "Napper." He stations himself at the front of his cage, apparently quiet and listless, and if an unwary visitor attempts to rouse him by thrusting out an umbrella or a hat, he instantly seizes the object with his powerful hands and tears it to pieces. Notwithstanding the utmost watchfulness on the part of the keepers, he has at present to his discredit 59 umbrellas and over 60 hats, among which is a policeman's helmet. He could not get this stiff object between the bars of his cage, but he managed to destroy it before it could be rescued.

South America is the home of the sloth, a creature with long, irregular limbs, that lives in the trees of tropical forests. It is of a very low order of development, seems to have little intelligence, moves slowly about on the trees, hanging head downward, the claws of its long arms clasping the branch above. Its body and limbs are covered with coarse, brittle hair on which, in the damp, hot air of the South American forest, a vegetable growth attaches, making the creature seem a part of the tree itself, thus successfully hiding it from view. When it is removed from its native forest into a drier atmosphere the green alga on its hair dries up and falls off, leaving the animal a dull gray, with or without stripes or other marks, according to the species to which it belongs. It is not at home on the ground, its legs not being adapted to walking. Its food is the young leaves and tender fruits of the forest trees. As is the case with most creatures of a low order, the sloth is a night roamer, taking his sleep curled up and looking like a moss-covered bole of a tree during the light of day, making his slow journeys and eating his simple food by night, when he probably sees better than in the day.

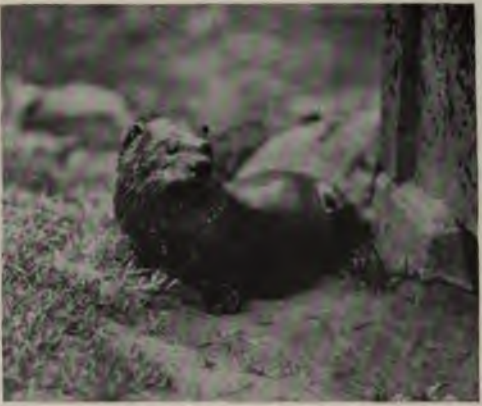
BEAVERS. SEALS. OTTERS.

Mention has already been made of the secluded valley, parallel to the main road through the park from the western entrance, in which are pools for the beavers and sea lions, together with other inclosures. Plate 21 shows the condition of this valley some years ago, when the work of the beavers was more extensive than at present.

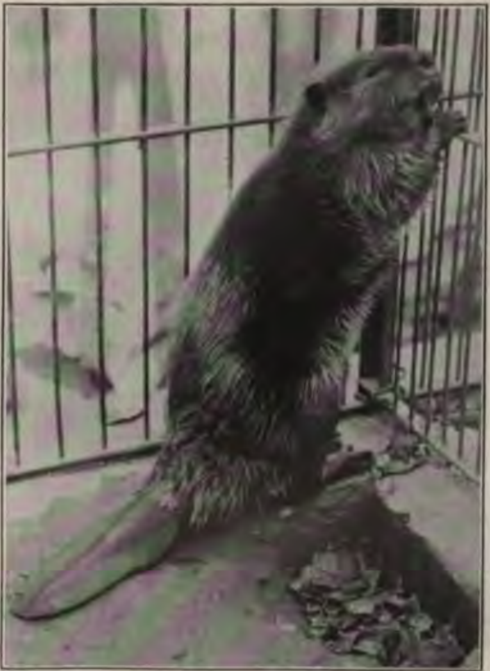
The American beaver, which resembles closely the European animal, was once very abundant throughout the United States and Canada. The Dutch company that founded the State of New York used the beaver as an emblem on the coat of arms of the colony because of its abundance and importance, and it is said that the Hudson Bay Fur Co. often exported more than 100,000 beaver skins per annum. Its fine, soft fur was a source of great profit to trappers and hunters. This led to a merciless pursuit of the animal, resulting in its practical extermination in the United States, it being now found only in thinly settled forest regions and in the Yellowstone Park, where it is carefully guarded and preserved.

Traces of its former existence may be seen in many parts of the country, consisting of dams, sometimes hundreds of feet in length and of very considerable width, evidently the result of long years of work of successive colonies of beavers. In the course of time these dams became solid embankments, upon which large forest trees flourished. Small ponds and lakelets were thus formed, these being particularly numerous upon the smaller affluents of the rivers of Canada, New York, Michigan, Wisconsin, and Minnesota. These ponds gradually filled up with growths of moss and other plants, forming a peaty bog from which trees were absent and which then supported grass. The early settlers termed this a "beaver meadow." The lower part of the city of Montreal is built upon such a formation, and there are many such in different parts of the United States. Not less than 54 towns in this country have been named from some natural association with the beaver.

The beavers in the park, following their natural instincts, have built, in all, three dams, two of which may be seen in plate 21. They did this work, enormous when considered in the aggregate, unaided, cutting down all unprotected trees and bushes within their inclosure, gnawing the trunks and branches into lengths suitable for transportation, dragging them for some distance, and piling them in a systematic manner across a little rivulet that meandered through the valley. Considering the means at their disposal, their method would do credit to any civil engineer. They place the bottom layer of sticks with the heavier ends downstream, intertwine them with sticks and brush, weight them down with stones where the greatest pressure is likely to occur, and plaster the whole with mud from the



YOUNG OTTER.



BEAVER GNAWING.

OTTERS AT PLAY.

THE SEA-LION POOL.

stream. The dam is in this manner built up until the water rises, forming a pond. The upstream side of the dam is nearly vertical, and in the course of time becomes fairly regular, the lower or downstream side being much more sloping and remaining rough. At first the water percolates through the interstices of the structure but as the dam gets more compactly settled the water rises nearly to its top.

Having completed the dam, the beavers proceed to build, on the edge of the pond, a house or lodge, pursuing the same method of construction by interlacing sticks. Within is a chamber, usually about 5 or 6 feet across and 18 or 20 inches high, having a firm, hard, level floor, made of small twigs and chips imbedded in earth, a few inches above water level. On this floor they place some dried grass or leaves. Here the beaver sleeps and rears his family. The lodge is entered from an inclined passageway commencing some 2 or 3 feet below the level of the water in the pond, the purpose of the dam being to raise that level sufficiently to conceal the entrance and thus protect the animal from its enemies.

The beavers are constantly at work repairing or altering the dam, sometimes cutting channels through it to lower the water, more frequently plastering it up and extending it. The dam now in the park, the third one built, has been repaired and reconstructed by them several times. This interesting work is done mostly at night; during the day the animals stay in their lodge and are not seen by visitors unless it be early in the morning or late in the afternoon. Like most nocturnal animals, the beaver does not see well in a bright light.

In a wild state the beaver feeds almost entirely on the bark or tender wood of the aspen poplar, the willow, or other soft-wooded trees. As he does not hibernate, he usually stores up a supply of twigs of this kind just before winter, immersing them in water near his lodge. In captivity he becomes accustomed to more civilized fare and eats bread, roots, and other vegetable products, and occasionally may get a little bark. In order to digest such refractory food, he has a large macerating pouch, larger indeed than his stomach, corresponding to the appendix of the intestine of man.

The beaver is enabled to do his extraordinary work by means of extremely strong chisel-shaped incisors, or front teeth, which are separated from the others by a considerable interval and are actuated by very powerful muscles. He will bite a broomstick in two with ease, and fells large trees with no aid whatever, merely by gnawing around the entire circumference. One of these trees may be seen in the upper left-hand corner of plate 21. If caught in a steel trap, a beaver will sometimes free himself by gnawing off the limb that is seized. In one instance this was done three times; so that the animal, when finally captured, had but one effective leg. The American Indians, before they became acquainted with the use of iron, used these formidable teeth of the beaver as gouges and chisels.

In other respects also the animal is excellently adapted for this work. He readily stands upright on his hind legs, as may be seen in plate 22. This is the posture he assumes when gnawing around a tree in order to fell it. His forelegs and paws are capable of holding and clasping, very much as do the hands and arms of man. It is with these that he carries his load of twigs, stones, and mud with which he builds. His hind feet are powerful paddles, and he can use his flat, scaly tail to guide him in swimming. When alarmed, he gives a resounding slap upon the water with his tail, dives, and seeks the security of his lodge.

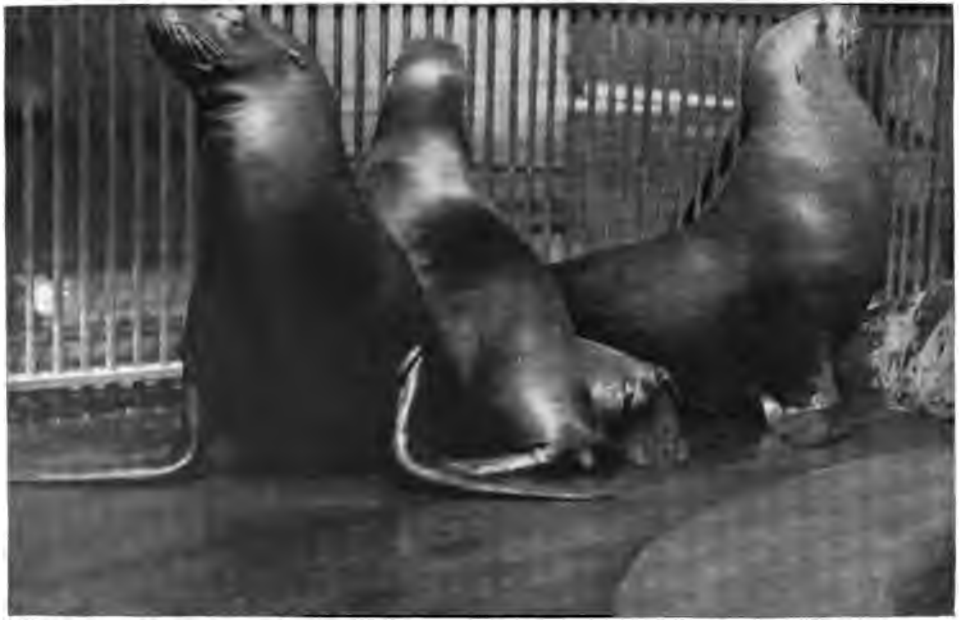
Near the pen in which the beavers are confined are smaller inclosures for gnawing animals of similar habits, such as the muskrat and the coypu or nutria.

The muskrat is a natural inhabitant of the park, colonies of them being found in several places along the banks of Rock Creek. More tolerant of civilization than his cousin the beaver, he is also more prolific, and is consequently found in considerable numbers throughout the United States. He is smaller than the beaver and, like him, lives in lodges made out of small twigs or in burrows hollowed in the banks of streams and ponds, the entrance being always under water. The fur is sold extensively, usually under some disguising name, as "river mink," or "Hudson seal."

The coypu, also called the nutria, the South American water rat, otter, or beaver, is a native of Argentina, Chile, and Peru. Its habits are like those of the muskrat.

Adjoining the beavers' inclosure is the sea-lion pool, an artificial basin some 96 feet long, 47 feet wide, and 6 feet deep, through which fresh water constantly flows. Visitors often ask whether these animals—in a wild state found only in salt water—can properly thrive in such a location. There has been no difficulty in keeping them in good health, for, being air-breathing creatures, they do as well in fresh water as in salt, provided they get plenty of food and exercise. Two different species are shown—the California sea lion, familiar to those who have visited the Cliff House, near Golden Gate, San Francisco, and the northern or Steller sea lion, a larger animal found principally in Bering Sea. The California species emits a loud, sharp bark, which it keeps up almost incessantly and which reminds one more of a dog than a lion, while the northern animal makes a roaring noise, remotely resembling that of a lion.

These animals swim with great rapidity and ease throughout the whole extent of the pool, gamboling and playing about each other, and it is interesting to see how expert they are in seizing the fish



STELLER AND CALIFORNIA SEA LIONS.

ALLIGATOR YAWNING.

which are thrown to them as food. On land they are clumsy and awkward, pulling themselves along by their flippers, which resemble a fish's fin rather than the limbs of a mammal, which they really are. When they wish to rest they seek some shelving spot on the gravel that surrounds the pool or perhaps crawl into the house of piled bowlders which may be seen at the lower end of their inclosure, where there is a plank floor and shelves on which they may lie in quiet.

Under the cliff at the southern limit of the park are found some near relatives of the sea lions. Here is a fur seal from the Pribilof Islands, the animal to which we are indebted for the sealskin used for articles of apparel. It was only recently that it was found possible to keep these creatures in captivity. This one was taken from its mother and reared on a nursing bottle like a baby. For a long time it would not eat the fish which was given it, but now it has become accustomed to that diet. It is one of the most graceful creatures imaginable when swimming in a tank of sufficient size to show its evolutions; but, like the sea lion, it progresses with some difficulty on land. The fur seal spends the winter in the open ocean, but betakes itself to certain definite localities on the shore during the summer and autumn for the purpose of rearing its young. When the time for this migration comes the seals, in vast schools, swim swiftly, unswervingly, often hundreds of miles, to their breeding place, showing that "homing" instinct so puzzling to naturalists.

Next are several harbor seals from the coast of Maine, intelligent looking little animals, with faces astonishingly human in appearance. One can easily conceive that the fable of the mermaids or mermen might arise from an indistinct view of these creatures through fog or mist.

In separate inclosures above the beaver pen are found the otters, animals that, like the seal, feed upon fish, and swim to catch them with great rapidity and ease. Unlike the seals and sea lions, they have well-developed and perfect limbs and are active and agile upon land, but when swimming in the water they look very much like small harbor seals. They are very playful and may often be seen swimming about balancing a small stone or pebble on their heads. Where the ground is suitable they make slides, down which they coast into the water, and they also do this in winter on the ice and snow. They have a curious habit of always wetting their food before eating it.

In captivity otters become very tame and readily come to the call of their keeper, or indeed of any visitor. They are so active that it is very difficult to photograph them. They have a strong antipathy to dogs and the sight of one puts them immediately in a rage. Though comparatively small, they are quite strong, and a full-grown otter has been known to kill a dog by seizing it by the nose, dragging it into the water, and drowning it. The dog can not well get hold of the otter because of its slippery coat.

Although a semiaquatic animal, always seeking a home near small lakes or streams, it is said to make quite long journeys overland from one watercourse to another, always going around or under obstacles, instead of climbing over them. It is widely but not profusely distributed from Canada to Florida, and closely related species are found in Europe and South America.

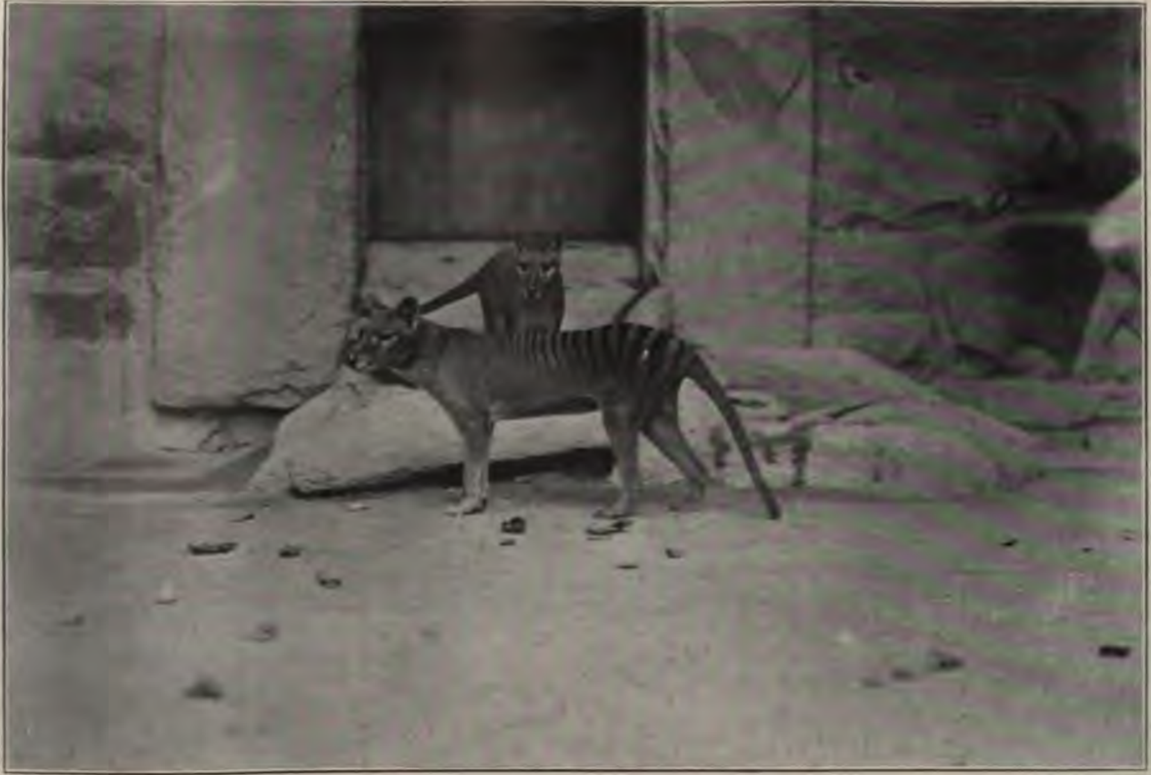
The fur is quite valuable and would probably be more generally used were it easier to obtain. Three thousand three hundred skins were reported to be sold in the June sales of the London market. This animal must not be confounded with the closely related sea otter, found only in the Arctic regions, which produces one of the most valuable furs known to commerce, but is now nearly extinct.

There can usually be seen at the park a number of other small fur-bearing animals, such as the marten, the fisher, the mink, and the striped skunk, a very interesting and sociable animal when deprived of his scent bags. The skunk is usually very easily tamed, and even in a wild state shows but little fear of man, relying rather upon the dread which its natural means of defense inspires. The black-footed ferret, an intelligent and active little animal from the plains of the West, may also be seen here, and its relative, the common ferret, used for exterminating rats.

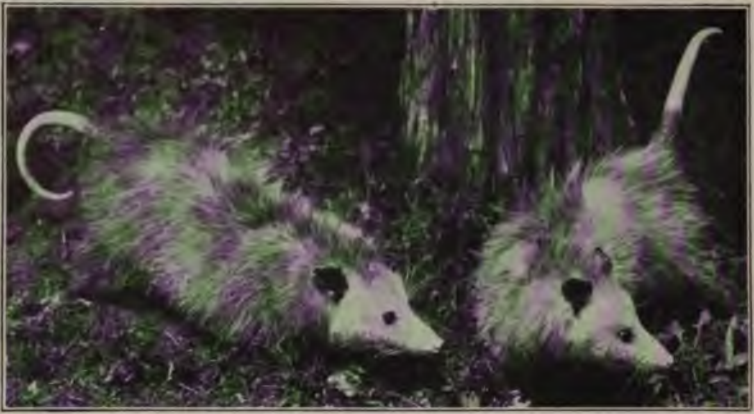
Neither are there wanting certain indigenous animals, the remnants of the original wild stock that inhabited the land before the park was established. Once, walking along the main road in the park, I chanced to meet a weasel who had so fearless and aggressive an attitude that I did not know but what he was about to dispute my passage. It is no doubt to such marauders that we owe the loss of a good many specimens from the ponds for aquatic birds.

THE ALLIGATORS.

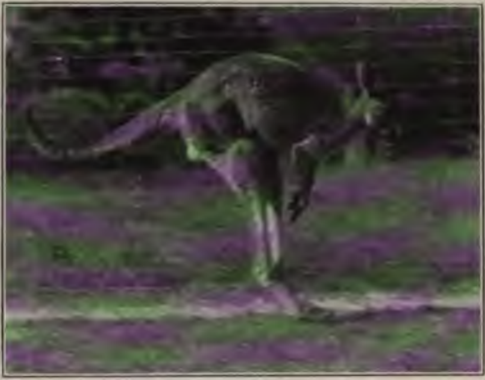
When the fur seals first came to the park there was built for them, close by the beaver pen, a fine swimming pool, but experience showed that this situation was too hot for them in our long summer days, and the pool was given over to the alligators, although they seem rather out of place here among the fur-bearing mammals. About a dozen of these unpleasant-looking saurians, of all sizes, may be seen here lazily basking in the sun. Let any unusual noise or movement occur near their inclosure and they at once scurry into the water, where they float, looking very much like submerged logs, with but little more than the nostrils, eyes, and dark knobby back visible. These animals were formerly quite common in the southeastern parts of the United States, but at present, owing to the demand for their hides and the fact that



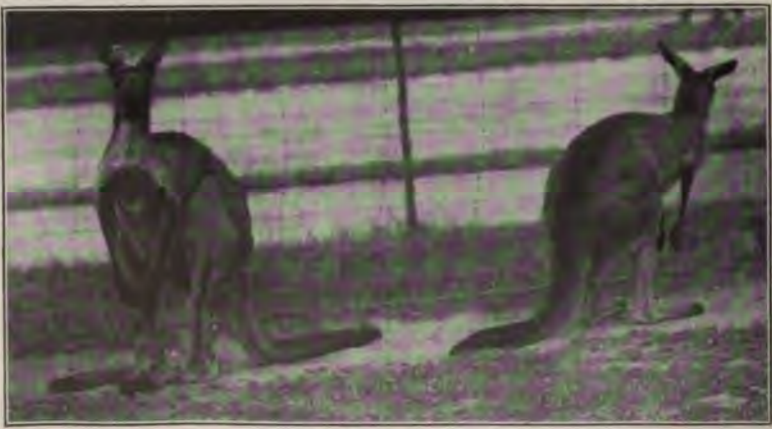
Thylacine or Tasmanian Zebra Wolf.



VIRGINIA OPOSSUMS.



KANGAROO LEAPING.



KANGAROOS STANDING.

tourists seem to take a particular pleasure in shooting them, have become comparatively rare. The demand is so considerable that they are reared for sale. Visitors to Florida often bring home young ones as curiosities, and then, as the creatures grow larger, find it inconvenient to keep them, so present them to the park. They grow rather slowly, the largest finally attaining a length of about 16 feet. The largest speciman at the park is not more than 10 feet long and has not grown in length since his arrival 20 years ago. In the warmer climate of its native haunts it might have reached a larger size. During the cold season alligators remain quite torpid, eating but little and moving about but slowly. They can not endure the cold of winter without protection, and in Florida they bury themselves in the mud. I am informed that one that escaped from confinement at White Sulphur Springs, W. Va., burrowed in beside a heating pipe, and came out safe and sound in the spring. When excited or angered they emit a peculiar hissing noise, and if they hear any distant, loud sound, like quarry blasting, they bellow like bullfrogs. Plate 25 shows the largest one in the act of yawning. They are not especially dangerous to man, but are very apt to snap up little dogs that come within their reach.

Their cousins, the crocodiles, are much more vicious, snapping and biting at anything approaching them. The few that have been at the park have been particularly hard to manage on that account.

THE POUCHED ANIMALS.

The park possesses a number of specimens belonging to the very interesting group of marsupials, or pouched animals, so called because their young, born at a very immature stage of development, are immediately transferred by the mother to a peculiar pouch on the belly, in which they remain for some months, attached to the nipples. Most of these strange creatures are found in Australia and the adjacent islands, where the ordinary forms of mammals are almost wholly wanting. Different habits of life have caused these animals to vary much as do those of other climes, and we have vegetable feeders, flesh eaters, and insect eaters, approaching in form the animals of similar habits in other regions. Thus there is a marsupial that the colonists have termed a bear, another somewhat like a cat, others resembling rats and mice, and one very like a flying squirrel.

One of the most striking forms is the so-called Tasmanian zebra wolf, or thylacine, shown on plate 26. This animal is also called the pouched dog, and is, in fact, more like a dog in appearance than a wolf. It is a flesh eater, and has been nearly exterminated by the farmers, who can not tolerate its incursions into the sheep pen and poultry yard. It is of a slate color, with black, zebralike stripes. It is found only in the island of Tasmania, where it lives in rocky caverns, coming out mostly at night.

To the vegetable-eating group of marsupials belongs the kangaroo, an animal that greatly excited the wonder of the discoverer, Capt. Cook, and his fellow voyagers when first discovered. As will be seen from the illustrations, it has very short fore legs and very long and strong hind legs. It seems rather awkward when walking on all 4 feet, but when disturbed gets over the ground with great rapidity by taking long leaps, sometimes of 20 feet. When sitting upright on its hind legs, supported by its tail, which is its usual posture, those of the larger species are as tall as a man. The colonists therefore gave to the adults of this size the name of "old man." In their native country they are usually found in flocks or droves of 50 or 60 animals, and, like sheep, invariably follow a leader when on the move. There they feed upon the tender young shoots of grass and other plants; in captivity they adapt themselves very readily to a diet of garden vegetables. There are a number of smaller tree kangaroos not larger than a house cat. In the park several kangaroos are kept during the summer in a large paddock, where they nibble grass and lie under the shade of the trees. At night they go into an open shed much as domestic animals would do. They are very timid and at any unusual sight or noise jump swiftly away. If they have their young with them, which is not infrequently the case, it is interesting to see the little ones jump hastily into their mother's pouches for concealment.

The only representative of the marsupials native to the United States is the opossum, which is, in fact, indigenous to the park and the surrounding country. This animal lives almost wholly in trees, and has a long, prehensile tail and clasping hands and feet that make it very expert in climbing. Its diet is quite miscellaneous, fruit, roots, birds' eggs, and small mammals all being acceptable. Like most other marsupials, it is most active at night and is dazzled by a bright light.

In the Southern States the opossum, when well fattened, is much esteemed by some as an article of food. During President Roosevelt's administration these animals were frequently sent him from different parts of the South and were then promptly turned over to the park.

Another pest of the farmers in Tasmania, which has earned its title by its fighting qualities, is the so-called Tasmanian devil, a short, stubbed animal with a large head. Although small, it can easily whip a dog of much larger size. In color it is black or very dark brown, with a white band or spot at the neck. Its teeth and jaws are large and powerful, and it cracks bones with the greatest ease. Retiring to the shade or to a cleft in the rocks during the day, it prowls about at night to prey upon other small animals, and even upon sheep, which it destroys in large numbers. Its general repu-

EUROPEAN HEDGEHOG.

TASMANIAN DEVIL.

ECHIDNA.

THE WOMBAT.

A RIDE ON A GIANT GALAPAGOS TORTOISE.

tation is bad, as it is said to be untamably sullen and savage. The specimens kept at the park do not seem to confirm this, as they have been reasonably docile, not unlike other animals of limited intelligence. It naturally shuns the light, stays in a dark corner of its cage, and, when disturbed, is likely to resent it by snarling. We are apt to forget that in captivity we place animals in extremely unnatural conditions and force them to endure the sight of man, who is to them an object of the greatest fear and distrust.

The park has quite recently acquired a wombat, one of the larger marsupials of Australia—a herbivorous animal that looks like an enormous woodchuck or groundhog, and it is not dissimilar in its habits as it is a burrowing animal living upon roots. It is sluggish and quiet in captivity, usually sleeping during the day.

The echidna, or spiny anteater, is another strange creature from Australia, being extremely interesting as showing the intimate relation which exists between the lowest mammals and birds. It is not very large, being from a foot to a foot and a half in length. It has a long, horny bill, no teeth, a slender tongue which it can protrude to catch the insects on which it feeds, and sharp spines are mingled with its hair. Though in a sense it suckles its young, it lays eggs as do birds and many reptiles. The specimen shown in plate 28 was at the park for some time. Its natural food is white ants, but as these were not available, it was fed mostly on finely minced hard-boiled eggs. It kept constantly hidden under the straw that was used as its litter. Mr. Le Souef, director of the zoological garden at Melbourne, informed me that when placed on soft ground it quickly burrows out of sight, and if pulled away clings to the soil by erecting its spines. He once saw one with a dead snake wound around it. The reptile had tried to crush it and had been pierced by its spines, leaving the echidna unhurt.

In superficial appearance the echidna is not unlike the European hedgehog shown in plate 28, specimens of which animal may usually be seen in the park. The latter is, however, only distantly related to the echidna, as it brings forth its young alive and is in many respects of a much higher order. In this animal also the hairs have been developed into spines which are used as a means of defense. On the slightest intimation of danger it rolls itself into a compact ball, with limbs and head perfectly concealed and sticks out its spines in every direction. It is able to do this by means of a powerful layer of muscle that lies immediately beneath the skin. This animal should not be confounded with the American tree porcupine, which, on account of the spiny character of its hairs, is often called a hedgehog.

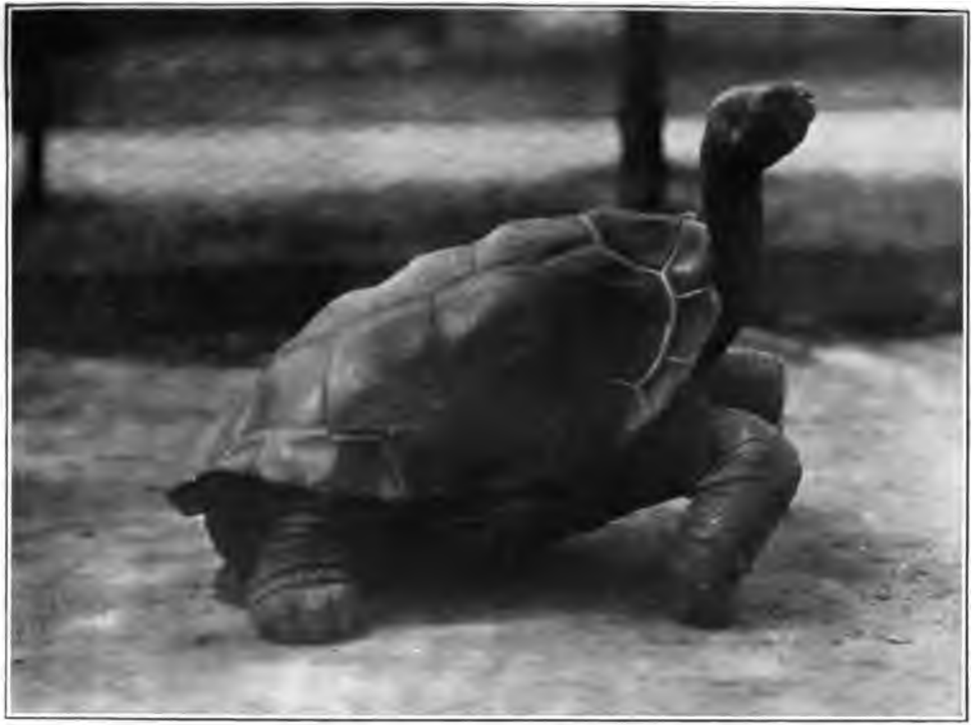
THE REPTILES.

The park does not as yet possess a perfectly appointed reptile house, consequently the few reptiles in the collection are exhibited in a somewhat unsatisfactory way in the lion house. There are to be seen a number of boa constrictors, an anaconda, several large rattlesnakes, a copperhead, a water moccasin, a number of harmless snakes, the celebrated Gila monster (a species of lizard), some iguanas, and last, but not by any means least, four giant tortoises from the Galapagos Islands.

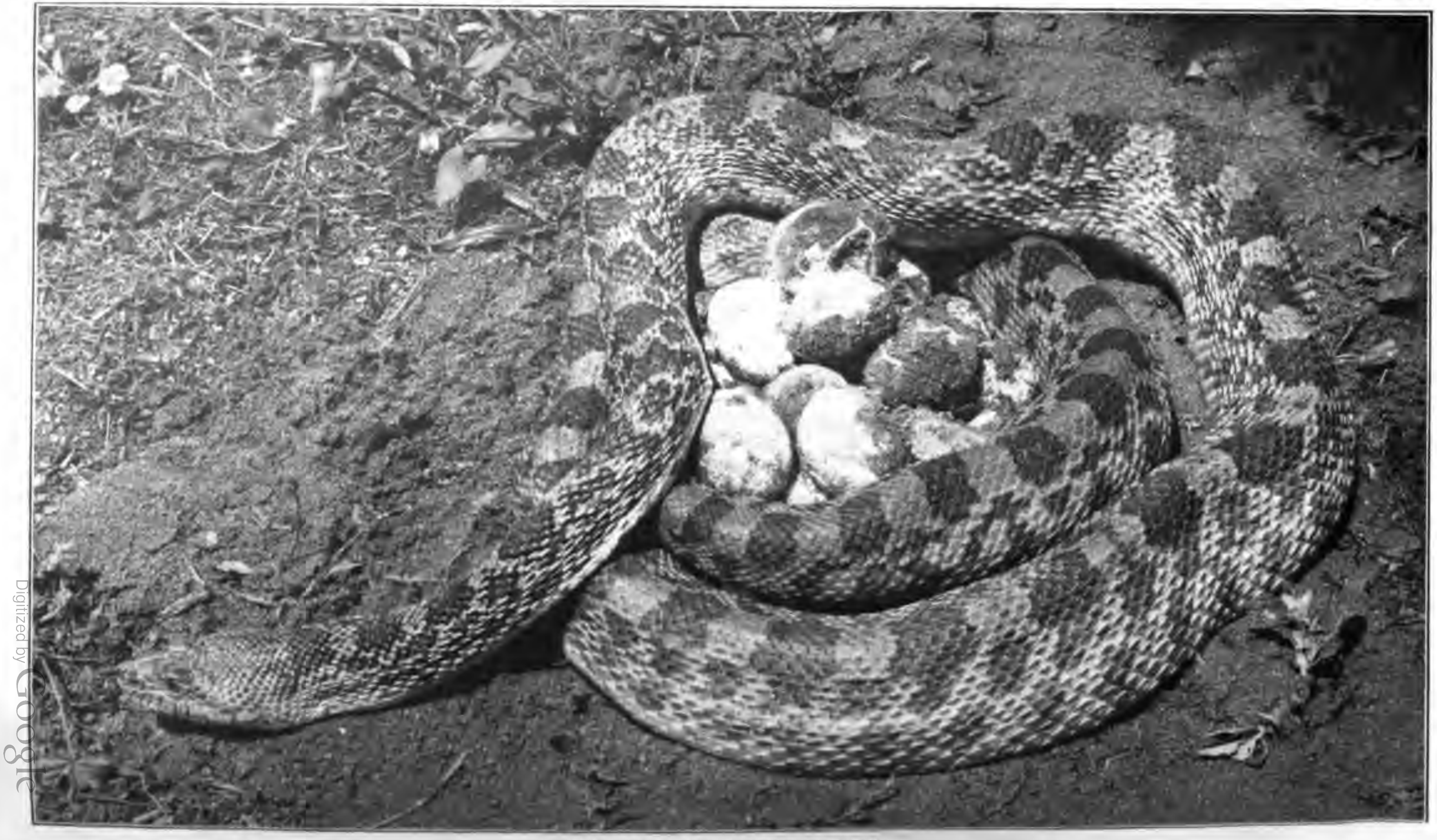
These tortoises are very interesting to naturalists, as they are the surviving representatives of gigantic reptiles that were formerly widely distributed over the surface of the earth, but are now nearly extinct. They exist only in scattered islands in the Indian Ocean and in the small volcanic group of the Galapagos, 500 miles west of South America, directly under the equator. They were formerly extremely abundant there, so much so that the Spaniards named the islands from them, the word "galapago" meaning, in Spanish, a land or fresh-water tortoise. Their abundance led, however, to their destruction, as they were found to be excellent food and easily caught, so that ships would stop at the islands and take on hundreds of them as a welcome supply of fresh meat. They are vegetable feeders, in captivity eating lettuce, cabbage, and other vegetables; when at home their principal food is a species of cactus and some acid berries. They are believed to be very long lived, specimens of the East Indian variety being known to be at least 200 years old. As they grow very slowly, it is probable that the specimens in the park are already of great age, though they are of moderate weight and size for these animals, the largest weighing only 170 pounds and measuring slightly less than 3 feet long, while specimens have been collected weighing 400 pounds and measuring 4 feet, and fossil specimens are known at least 6 feet in length. They are quite strong and easily walk off with a small boy or even a man upon their backs, as may be seen in plate 29.

Mr. Walter Rothschild sent an expedition to the islands in 1897, and it is from him that these specimens were obtained. They represent two different species, inhabiting two different islands, for, strangely enough, those in each separate island have peculiarities slightly different from the others. The following account of these interesting creatures is from the Journal of a Cruise to the Pacific Ocean (1812–1814), by Capt. David Porter, United States Navy:

> They [the ships] had been in at James Island and had supplied themselves abundantly with those extraordinary animals, the tortoises of the Galapagos, which properly deserve the name of the elephant tortoise. Many of them were of a size to weigh upward of three hundredweight, and nothing, perhaps, can be more disagree-



GIANT TORTOISE FROM THE GALAPAGOS.



BULL SNAKE INCUBATING ITS EGGS.

able or clumsy than they are in their external appearance. Their motion resembles strongly that of the elephant; their step slow, regular, and heavy; they carry their body about a foot from the ground, and their legs and feet bear no slight resemblance to the animal which I have likened them; their neck is from 18 inches to 2 feet in length and very slender; their head is proportioned to it and strongly resembles that of a serpent; but, hideous and disgusting as is their appearance, no animal can possibly afford a more wholesome, luscious, and delicate food than they do. The finest green turtle is no more to be compared to them in point of excellence than the coarsest beef is to the finest veal, and after once tasting the Galapagos tortoise every other animal food fell greatly in our estimation. These animals are so fat as to require neither butter nor lard to cook them, and this fat does not possess that cloying quality common to that of most other animals; and, when tried out, it furnishes an oil superior in taste to that of the olive. The meat of this animal is the easiest of digestion, and a quantity of it, exceeding that of any other food, can be eaten without experiencing the slightest inconvenience. But what seems the most extraordinary in this animal is the length of time that it can exist without food; for I have been well assured that they have been piled away among the casks in the hold of a ship, where they have been kept 18 months, and, when killed at the expiration of that time, were found to have suffered no diminution in fatness or excellence. They carry with them a constant supply of water, in a bag at the root of the neck, which contains about 2 gallons; and on tasting that we found in those we killed on board, it proved perfectly fresh and sweet.

As to the other reptiles in the lion house, it may be of interest to note that some of them have bred in captivity. Plate 31 shows a bullsnake coiled about its eggs, evidently brooding them as a bird might do. When hatched out the young are left to shift for themselves. Some species of snakes bring forth their young alive. That is the case with the tree boas, one of whom gave birth to 64 young at once, puzzling the park authorities very much to know how to care for so numerous a progeny. A number of them were presented to other zoological collections; others remained in the park and grew to considerable size.

The unnatural conditions which necessarily prevail in captivity make it difficult to keep snakes in perfect health. It seems quite clear that, in spite of the popular impression as to their aggressiveness, they are really quite timid creatures. They often refuse to eat, remaining for long periods without food. It is quite astonishing how long they will live without taking a particle of nourishment. In several instances they have been known to survive for more than a year. About two or three times a year snakes shed their skins entirely, even to the horny covering that protects the eyes. The skin usually strips off in one entire piece, and the reptile appears in a new and much more brilliant suit.

THE FLYING CAGE.

Lovers of birds found very early that the confinement of these winged creatures within the limits of a small cage did not display their activities or beauties to the best advantage and so invented for their more effective exhibition large inclosures in which they might have some opportunity for flight. Such an inclosure is called in French a "volière," or place for flying. We have no perfectly satisfactory word for it in English, and have adopted the rather clumsy and misleading substitute of "flying cage." There are several such large cages in the National Zoological Park. It is necessary, of course, to separate the eagles, owls, hawks, vultures, and other predacious birds from the less aggressive ones, and the larger running birds can not well be shown in this way.

The large cage shown on Plate 32 is 158 feet long by 50 feet wide and 50 feet high, and is situated in a lovely valley near the western entrance to the park. It is built over several full-grown trees and has a streamlet of water running through it which supplies small pools for the convenience of the birds. It contains a considerable variety of medium-sized birds, mainly those that like to live near water, such as herons, storks, cranes, cormorants, etc. The night herons have made themselves very much at home there, building their nests and rearing young in considerable numbers every year, so that the park has been somewhat embarrassed by their rapid increase. Attracted by the apparent comfort of their kind, wild herons come and build also in the trees about the cage.

Much larger cages than this have been erected. The one built by the park at the St. Louis Exposition in 1904 is 228 feet long, 84 feet wide, and about 55 feet high. It was intended to bring this cage to the National Zoological Park, but the city of St. Louis desired it to remain there.

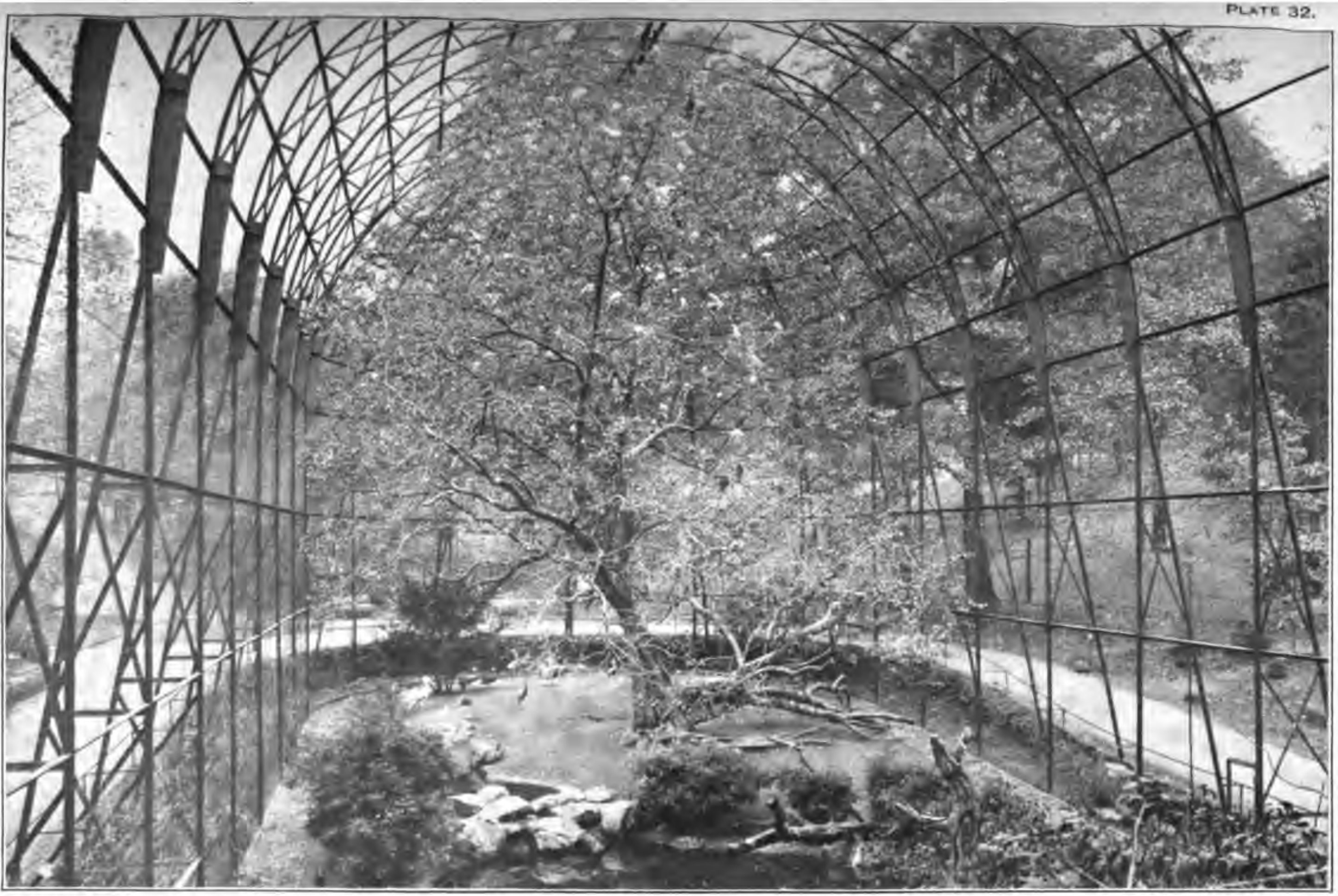
It will be impracticable to give within the limits of this article anything more than a brief note of some of the principal birds in the collection at the park. Only a few are mentioned.

THE TOUCAN.

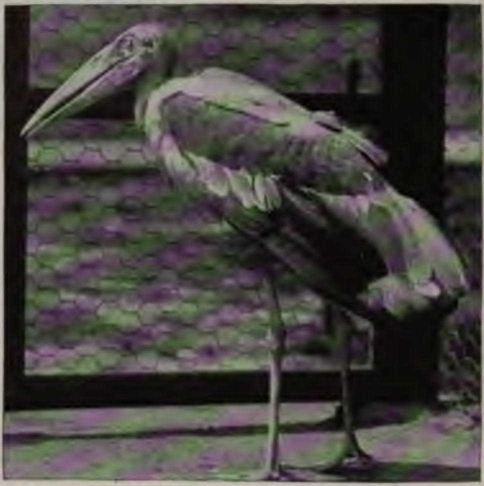
This noisy bird comes from the forests of tropical America and many species are found in the Amazon Valley. Its enormous bill, which one would think would overweight the bird, is really very light and does not at all interfere with flight, though it is somewhat awkward while eating, as the bird has to throw its head back to allow morsels to reach its throat. Its plumage varies much in different species, but is always very showy—jet black or very dark green, being set off by brilliant yellow and scarlet. Like our crows, these birds congregate and call to each other with raucous cries, and are especially excited if they discover an owl.

THE MARABOU.

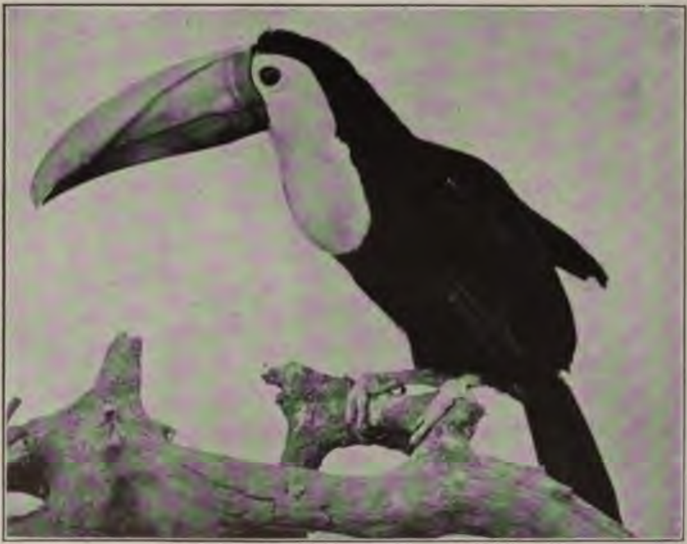
If you observe a large, silent, sedate bird scanning you critically and judicially with a military air, that is the marabou stork, or adju-



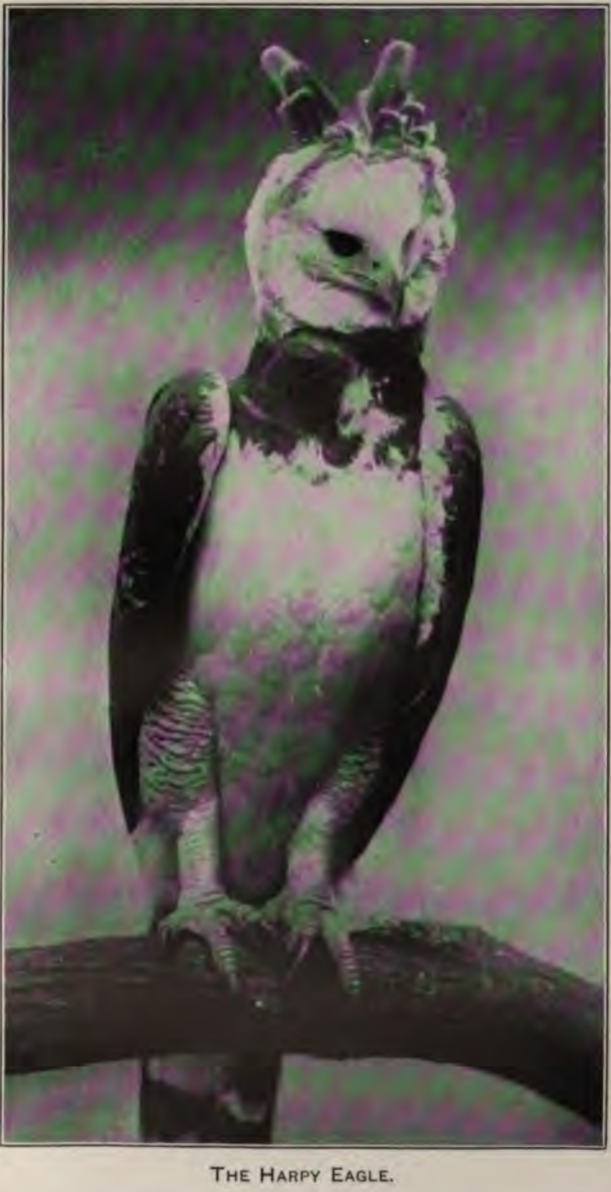
THE FLYING CAGE.



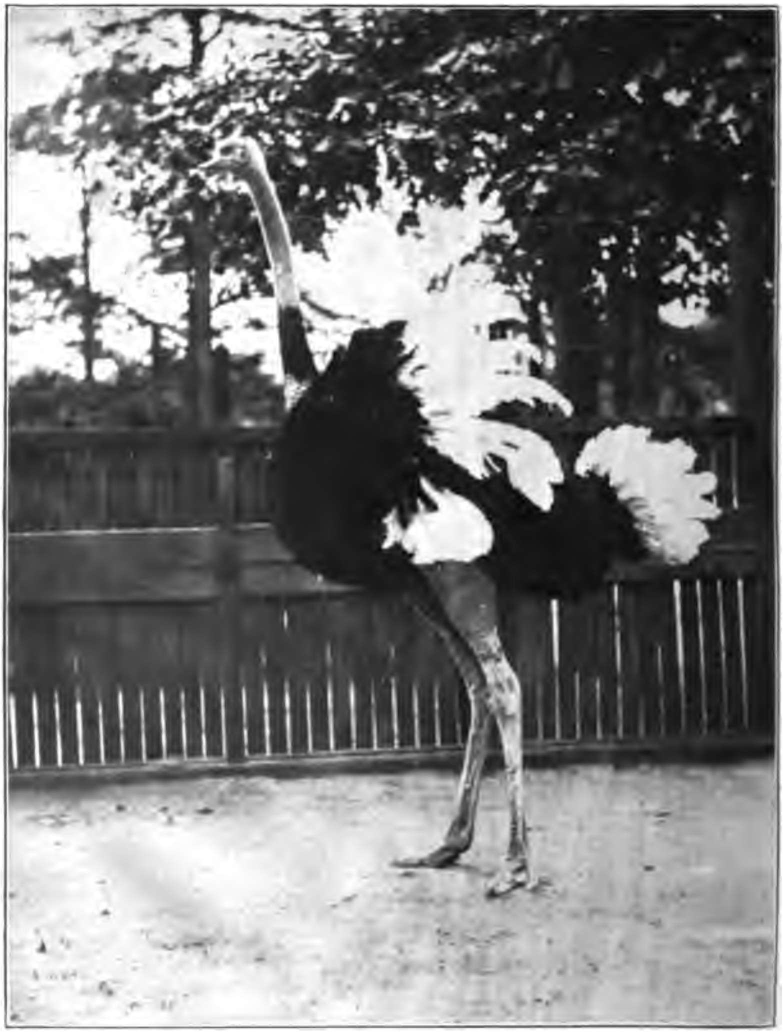
THE MARABOU.



THE TOUCAN.



THE HARPY EAGLE.



THE OSTRICH.

tant, a name given to it from its severe aspect. Great flocks of them are seen in eastern countries, where they serve as scavengers. It has a curious way of reposing by bending its legs and resting on what is really the tarsus. From this bird come the marabou feathers so much prized for ladies' boas. The specimen at the park is from India, but there are closely related species in Africa and Java. In front of its neck there may be seen a large throat pouch, connected with the respiratory apparatus, which has puzzled naturalists a good deal, as its functions are not exactly known. It has been thought to assist the lungs by affording a reservoir of air during rapid feeding, also to give additional resonance to the voice, or to attract the female by its expansion while strutting. The bird is a very silent one, and its mating habits have not been carefully observed, as it seeks seclusion upon the highest points of inaccessible rocks.

THE HARPY EAGLE.

In 1899 the United States sent a naval vessel up the Amazon as far as Iquitos, Peru, with a view to obtaining information regarding the commercial development of the country. The Secretary of the Navy kindly instructed the commanding officer to collect for the park such animals as could be readily obtained without impeding in any way the expedition. A number of important additions to the collection were secured, one of the most beautiful being the harpy eagle. This kingly bird was presented by the governor of the Province of Amazonas, Brazil, at Manaos, and came from the upper Amazon. Plate 34 does not do justice to its imperial air and lordly presence. It created a considerable sensation when carried through the streets of New York to be shipped to Washington. Its nature is by no means expressed by the name which has been given it. The harpy of Grecian mythology was a ravenous, unclean creature having the head of a woman and the wings and claws of a bird. Readers of Vergil will recall that when Æneas and his companions reached in their wanderings the Strophades, two little islands in the Ionian Sea, they were attacked while eating by the harpies, who, when driven away, prophesied dire calamities to the Trojans. Our eagle does not deserve such a name, for it is clean and dainty, proud as a Spanish don, and very fond of attention. It raises or lowers the crest upon its head at will, and it delights to spread its great wings and sidle along its perch at its keeper's call. If it is shown a monkey, it is at once excited and flutters and seizes the bars of its cage in attempts to get at it. Monkeys probably constitute most of its food when in its native haunts, but it also attacks peccaries, sloths, and fawns. The bird is found throughout tropical America as far north as southern Mexico.

THE CONDORS.

These great birds, the largest of all the birds of prey, inhabit the high mountain regions of North and South America, having their nests on almost inaccessible peaks. Both the Andean and the California species are seen in the park. The South American form is slightly the larger, but either bird is very impressive when it spreads its wings fully. It is interesting to see them do this on a hot day to cool themselves, or after a rain to dry their feathers.

The California condor shown in plate 36 is a young bird not yet in full plumage. He was very playful, and delighted to untie the shoestrings of his keeper while his cage was being cleaned. It seems almost a pity to confine in a cage birds whose delight is apparently to wing their way through the upper air over great mountain ranges. The California species is nearly extinct, being now found only in the most inaccessible parts of the Sierra Nevada. It was formerly abundant throughout California and Oregon. The park is fortunate in possessing three specimens. They are kept by themselves in a flying cage.

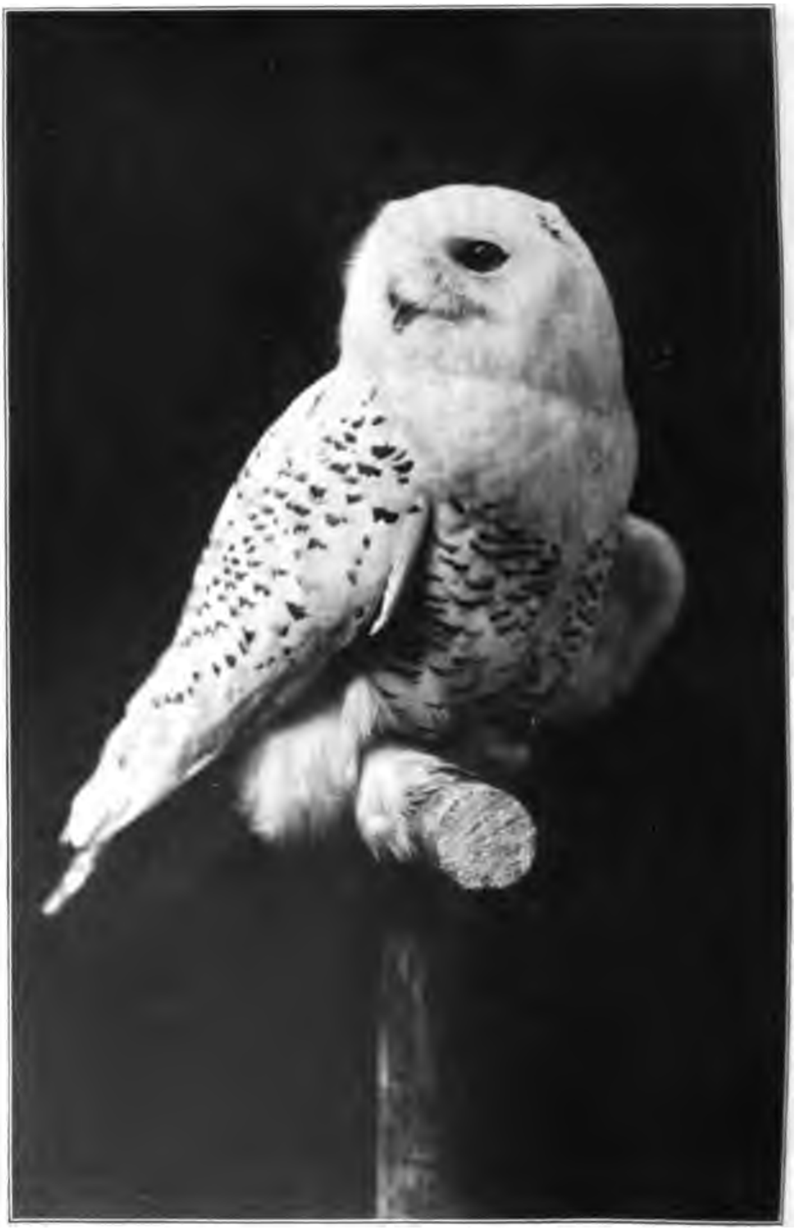
THE OSTRICH.

Since the extinction of the gigantic moas of New Zealand the ostrich is the largest of living birds, a fine male sometimes measuring nearly 5 feet to the top of its back and being able to look over a 9-foot fence, the height being due to the length of the legs and the neck, the size of the body not being proportional. The head is small and flat, with a short broad beak; the neck is practically bare of feathers, as are also the slender legs and muscular thighs, which naturalists have compared to those of a camel. This undressed appearance is fully compensated, however, by the luxuriance and beauty of the plumage of its body and wings. In the female the color is a somber gray, while the male is dressed in black, with wings and tail bordered with snowy, glistening white. These are the feathers which have been prized in all countries from the earliest times. Formerly they were procured only from the wild bird by hunting, but to-day ostrich farming is a recognized industry in many places, both in this country and in Africa.

The bird is a native of the deserts of Africa and Arabia, where its great height enables it to descry its enemies at a great distance, and its long legs and peculiar feet, especially adapted for traveling in sand, usually outdistance its pursuers. A wise hunter while pursuing on one horse will place a relay at a point at right angles to the course, as it is known that the bird will travel in a large circle. When finally exhausted the bird tries to hide in a shadow, with its tall head concealed behind a projecting rock, which is probably the origin of the fable concerning his hiding his head in the sand. This and other

THE CALIFORNIA CONDOR.

THE CASSOWARY.



THE SNOWY OWL.

tales of his digesting iron nails and similar objects have led to the popular belief that his intelligence is very low. It is a fact that he readily picks up hard, bright objects and pebbles to assist in the trituration of his food, as our own barnyard fowl does in a lesser degree, and in repairing his paddock care is taken not to leave wire clippings about. From the small head of the bird it might seem that the brain matter was rather deficient, but it appears from recent investigations that many functions of the brain of higher vertebrates are in his case performed by the large and well-developed spinal cord.

The park has two species of ostriches—one presented by King Menelek, of Abyssinia; another from South Africa. It has also a number of birds that are near relatives to the ostrich, such as the rhea, or South American ostrich, and the emeu that represents this family in Australia.

THE CASSOWARY.

Closely allied to the ostrich is the cassowary, from New Guinea and Australia—a large bird, with rudimentary wings, blue-black plumage, highly colored neck and wattles, and a helmetlike crest. Unlike the ostrich, these birds are lovers of the forest, and are said to use this strong helmet to part the branches of the dense scrub in which they live and which they traverse at great speed, quite baffling the hunter. When captured they are very readily tamed and breed well in captivity.

THE OWLS.

There are usually several species of owls in the park, as they are frequently found in the vicinity by farmers, who consider them as "vermin," overlooking their value as exterminators of rats and mice. At the inception of the collection, when it was kept at the back of the Smithsonian, a colony of barn owls was discovered in one of the towers of that institution. This species is not, however, generally known to agriculturists, and we are often asked to identify a "rare bird which no one in the neighborhood has ever seen," and find that it is the tawny barn owl, which from its peculiar facial coloration has been given the name of the "monkey-faced" owl. The horned owl, the barred owl, and the screech owl may usually be seen here. The beautiful snowy owl in plate 37 is a visitor from the North, its home being within the Arctic Circle, whence it comes southward in the winter in search of food, being occasionally seen even in this latitude. Unlike some of the owls it sees well by day.

THE GULL.

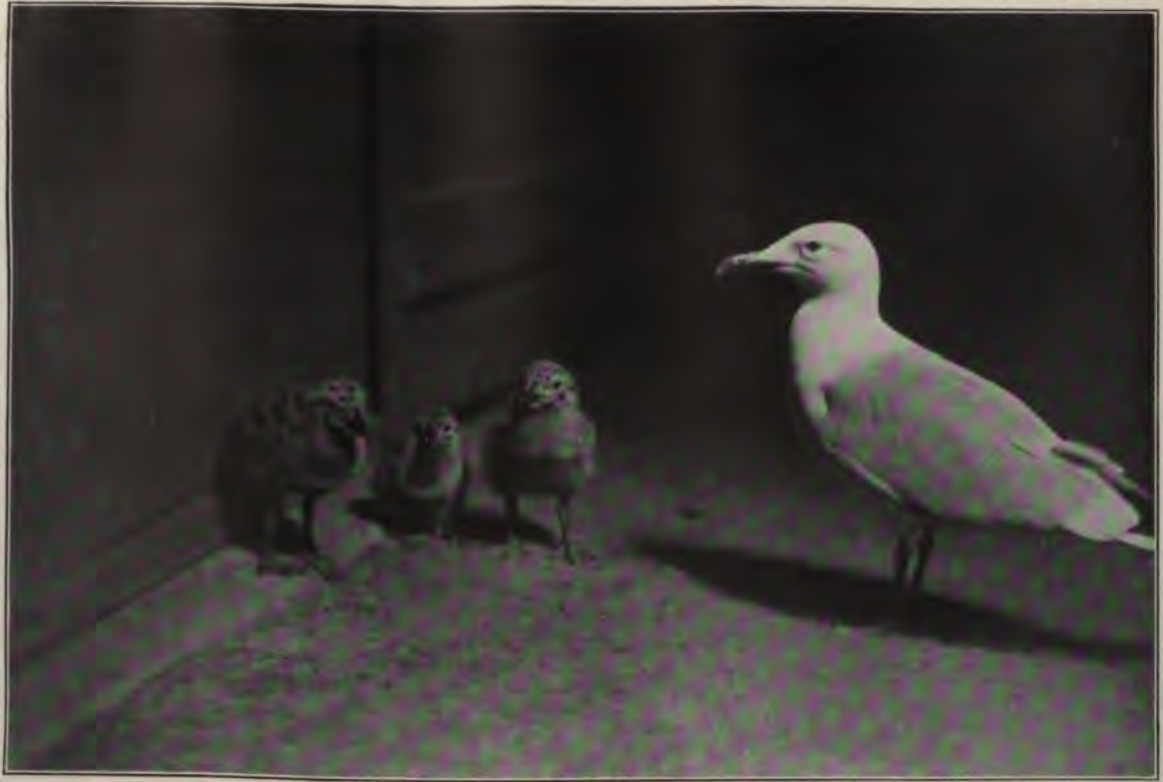
Everyone who has seen the ocean or a big lake knows the gull that follows steamers halfway across the Atlantic and ascends every great river far inland, with tireless and powerful flight. It seems strange and out of place in captivity, yet holds its own well among other web-footed birds. When nesting, it seeks some secluded spot—an island far offshore, a headland jutting out into the waters—and there lays its eggs and hatches its brood. Thousands frequent the same nesting places, and their cries are loud and unceasing. The interest in this particular specimen is that she hatched her chicks in the flying cage at the park, and they ran about as unconcernedly and with no more timidity than the chickens in a barnyard.

THE PELICANS.

These curious birds are distinguished by a large appendage like a leather bag attached to the lower jaw, by means of which they catch the fish which form their only food. When they wish to feed their young, they bring the nestlings close to their breast and disgorge some partially digested fish into the pouch for the little ones to eat. An imperfect observation of this peculiar method led to the story, once current, that the mother bird wounded its own breast and allowed the blood to flow into the mouths of its young, who were nourished in this self-sacrificing manner. The illustration on plate 39 is from Gesner's Historia Animalium, published in 1555. This old work, in four folio volumes, is a very erudite compilation of the knowledge of that time regarding animals. It will be noticed that the artist has not shown the pouch of the bird. This subject was a favorite one in heraldry during the Middle Ages, being used particularly in ecclesiastical institutions.

There are at present four species in the park. The brown pelican from eastern Florida and the Gulf coast is found only near salt water. Thousands of them may be seen on Pelican Island, in Indian River. They go often long distances for their fishing, proceeding in a very regular manner in a diagonal single file, the whole group beating the air in unison for a few strokes and then sailing until the leader commences to beat again.

The illustration on plate 40 shows the American white pelican received from the Yellowstone Park, where there is a colony on an island in Yellowstone Lake, from which each year they migrate to the Gulf at the approach of winter. They are among the largest of our native water fowl, having a spread of wings of 8 or 9 feet. During the mating season each male bird has a curious protuberance on the upper part of its beak, which drops off as soon as the young are hatched. They have wonderful powers of flight and delight to perform evolutions in the air and upon the water. Their plumage is of a glistening snowy white, and when standing erect, like the bird in the foreground of the group, they present a most noble and striking appearance. It is thought that this species once extended much farther north, even to the shores of the Arctic Ocean, migrating south-

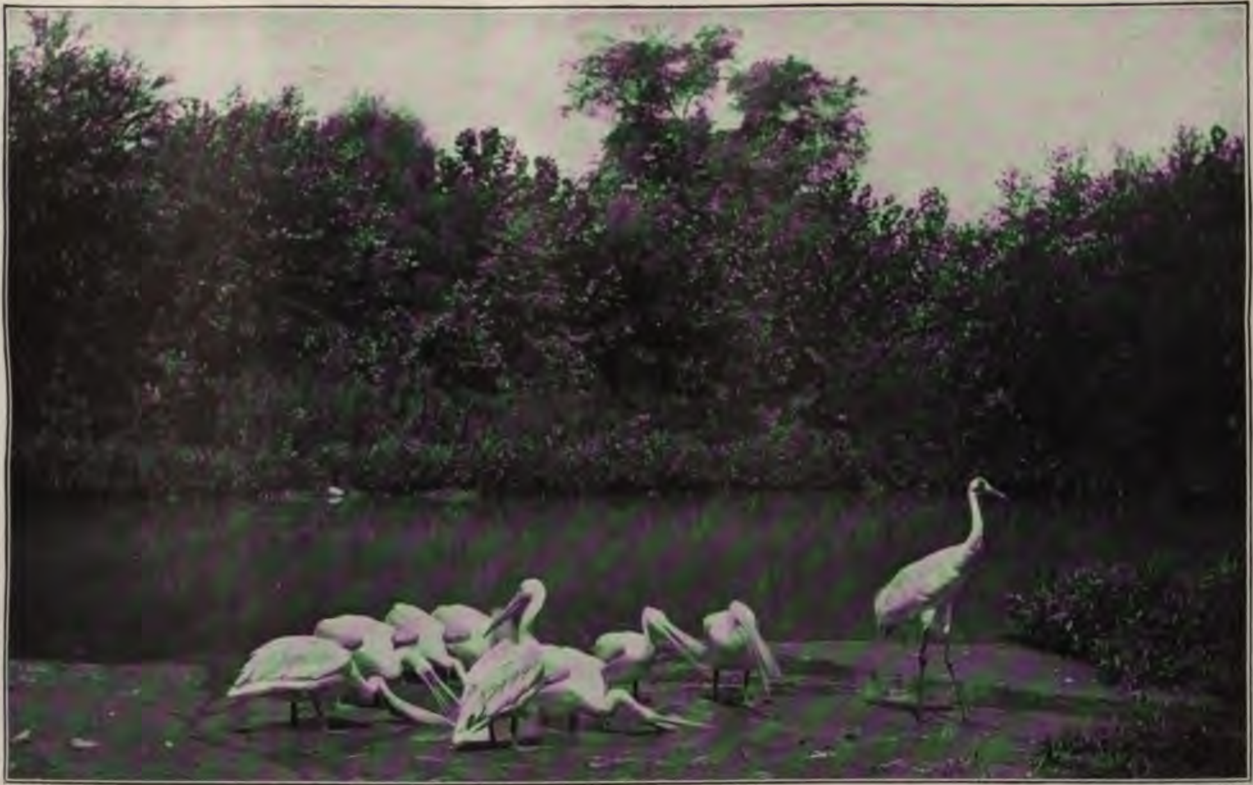


HERRING GULL AND HER BROOD.

THE FLAMINGOES.

PELICAN FEEDING ITS YOUNG

VARIOUS DUCKS.



AMERICAN WHITE PELICANS AND WHOOPING CRANE.

EUROPEAN SWANS.

ward at the approach of cold weather. In the park they remain out until it is so cold that their pond freezes over, when they are picked up bodily and taken in a cart to the protection of a house.

The whooping crane seen in plate 40 became very much attached to this group of pelicans, and also very tame. When they were transferred to their winter quarters, he followed on behind the cart of his own accord, fearing that he might be left behind. There must have been something unusually attractive about this crane, for when, one season, he was placed in the flying cage, a young demoiselle crane, of a totally different species, became his inseparable companion.

THE FLAMINGOES.

Another very interesting water bird is the flamingo, formerly breeding on the Florida coast, but now rarely seen there. Two large colonies have been found on one of the Bahama islands. Other species exist in India and in southern Europe and northern Africa. It is preeminently a wading bird, as, with its long legs, it stands 4 or more feet high. It has a most peculiar beak, that looks as if it had been bent downward about the middle, and both jaws are fringed with little platelets, by means of which the bird strains out the water after it has scooped up from the muddy bottom the mollusks and water plants that constitute its food. The body plumage is a beautiful rosy pink, which, unfortunately, has a tendency to fade in captive birds.

It is only quite recently that the nesting habits of the flamingo have been known. It was formerly supposed that, finding a difficulty in accommodating its long legs, the bird built up a hillock of convenient height and then sat upon it astride while incubating. This bizarre idea is now believed to be without foundation.

THE SWANS.

From the most ancient times the swan has been famed for its beauty and grace. It does not appear to advantage on land, as its widely set legs, meant for propulsion in water, give it a waddling gait; but when floating at ease, it is one of the most elegant of birds. The species shown in plate 41 is the European white or mute swan, so called because it has no singing note. It will, however, hiss like a goose when attacked. The poets from Homer down have ascribed to it the faculty of singing just before death, and Plato makes Socrates say, referring to his own approaching doom, that they sing not from sadness, but rather from joy, because they feel themselves to be immortal and about to return to Apollo. It is indeed probable that the bird in a wild state has a trumpet-like call. These birds have regularly nested in the park each year, the female incubating the eggs while the male mounts guard near by to drive away intruders. Even this is not always effective, as the small boy of the period, one of the most predacious of animals, sometimes succeeds in evading the vigilance of the watchmen and robbing the nest. The little nestlings, or cygnets, are covered with a soft gray down, which lasts for some months.

The ancients evidently supposed that swans must always be white, for the Latin poet Juvenal was the author of the well-known satirical comparison, "as rare as a black swan"; but they knew nothing of Australia, which has given us a fine jet-black species, which may be seen in the park. We also have two beautiful American species—the whistling and the trumpeter swans.

THE DUCKS.

In the valley below the flying cage a little pool has been formed and an inclosure in which a number of varieties of ducks may be seen. One of the most striking of these is the mandarin, whose particolored and checkered plumage has been compared to a crazy quilt. A number of these were presented to the park by the zoological garden at Tokyo, Japan, through the good offices of Dr. Alexander Graham Bell. Another very beautiful duck is the American wood-duck, not so bizarre in appearance as the mandarin, but possessing almost as great a variety of plumage. The redhead, the pintail, the shoveler, and the mallard may also be seen.

ON THE HABITS AND BEHAVIOR OF THE HERRING GULL, LARUS ARGENTATUS PONT.[1]

By R. M. STRONG.

[With 10 plates.]

I. INTRODUCTION.

It is the purpose of this paper to describe the results of work which was begun with the idea of studying bird habits intensively. I learned through Mr. Henry L. Ward, curator of the Milwaukee Public Museum, that colonies of herring gulls were to be found breeding on islands off both coasts of the peninsula which forms Door County, Wis., i. e., in Green Bay and in Lake Michigan.

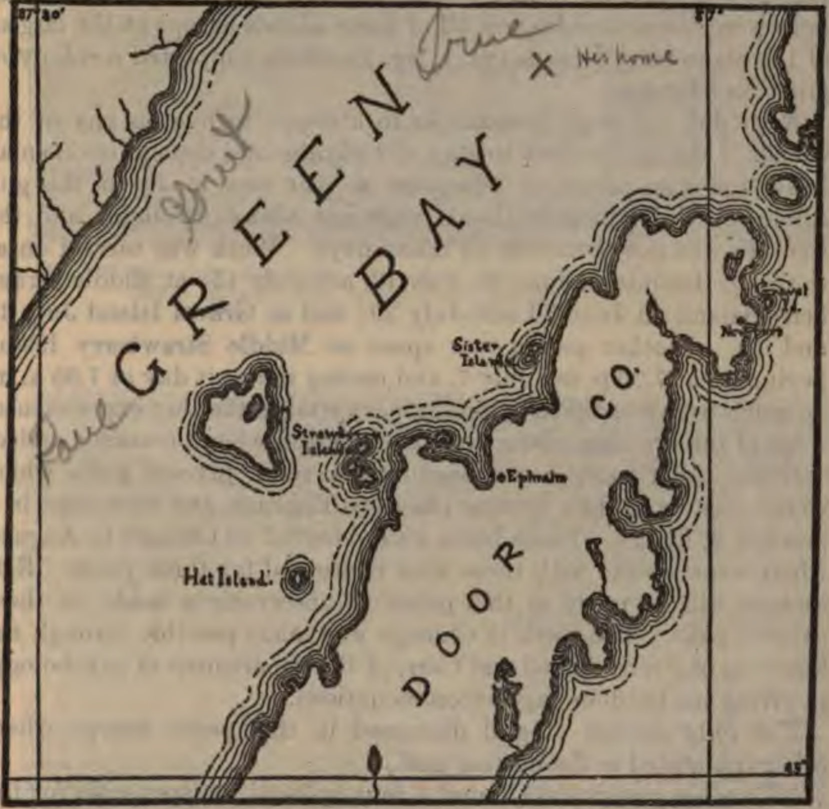


FIG 1.—Map showing locations of gull colonies in region of Green Bay, Wisconsin.

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[1] This paper is reprinted in abridged form from the original which appeared in The Auk, vol. 31, Nos. 1-2, January-April, 1914, pp. 22-49, 178-199; pls. 3-10, 19, 20. For a more detailed account, especially from the standpoint of the literature, the reader is referred to the original paper.

These birds seemed to be especially favorable for my purpose because (1) they nest in rather compact colonies on the ground and in more or less open places so that many individuals can be seen and studied to advantage, and (2) their considerable size and largely white plumage make them among the best bird subjects for the indispensable photographic records. Furthermore, I had already had some experience with these birds, especially during July, 1907, when I visited a breeding colony at Gull Island in Lake Superior, near Marquette, Mich.

On June 20, 1911, I made a preliminary exploring trip in Green Bay, starting from my headquarters at Ephraim, Wis. With the aid of a motor boat, the Strawberry Islands, the Sister Islands, and Hat Island were all visited during the day, and colonies of herring gulls were found breeding on all of these islands except at the largest of the Strawberry Islands (pl. 1, fig. 1), which supported a colony of great blue herons.

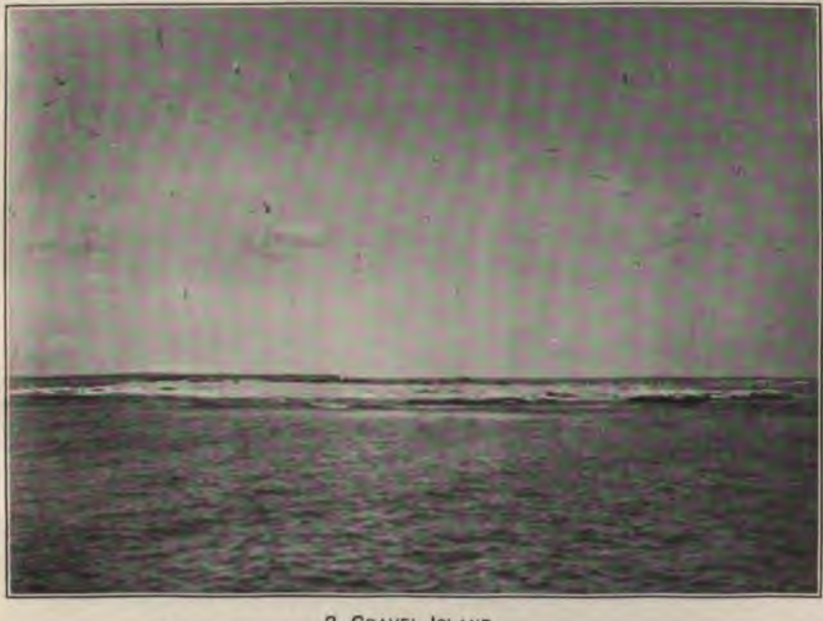
As it did not seem practicable to attempt to live on any of the islands, I thought it best to stay at Ephraim and depend upon small boats for transportation whenever a visit was made to the gull colonies. Unfortunately, boats were not always available and the weather was not favorable on many days. Work was carried on at the Sister Islands on June 26, July 12, and July 15; at Middle Strawberry Island on June 30 and July 29; and at Gravel Island July 18 and 19. Another period was spent at Middle Strawberry Island beginning at 7.20 p. m., July 7, and ending the next day at 7.05 a. m. So much time was taken by preliminary studies that my experimental work at the breeding places was barely begun when the season ended.

Other experiments were begun with some juvenal gulls which were taken from their nesting places to Ephraim and were kept in a pen (pl. 2, fig. 2). These birds were removed to Chicago in August, where experiments with them were continued for three years. References will be made in this paper to observations made on these captive gulls. The work in Chicago was made possible through the kindness of Profs. Angell and Carr, of the department of psychology, in giving me outdoor cage accommodations.

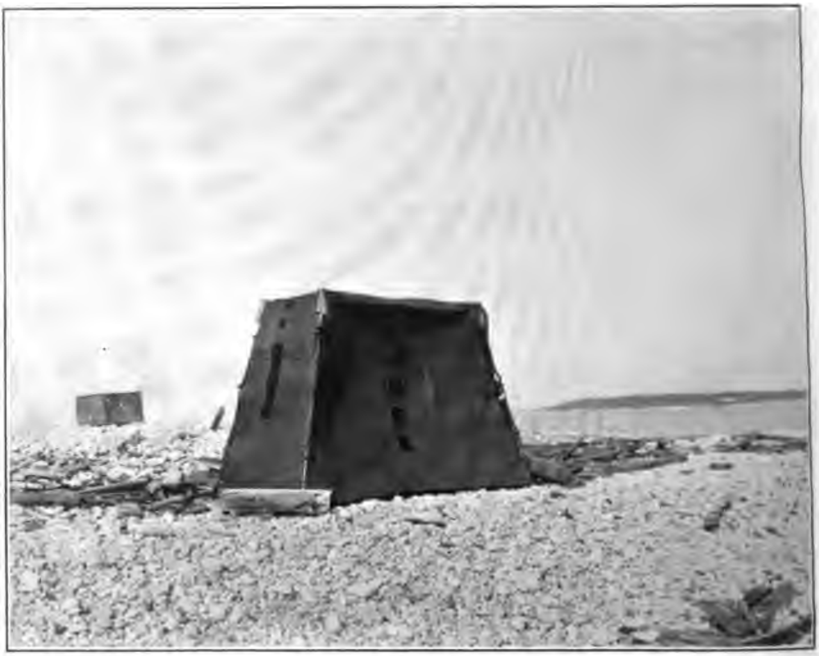
The only species of gull discussed in this paper except where otherwise stated is the herring gull.

Like other observers, I found a tent or blind indispensable for the study of the birds at their breeding places. On approaching a breeding colony of gulls a wild panic begins, which does not cease so long as the intruder appears to be in the immediate vicinity. If a companion enters the tent with the observer and then goes out again, leaving the place, many birds, at least, fail to notice that only one of the two men has left, and they very soon resume their usual activities.

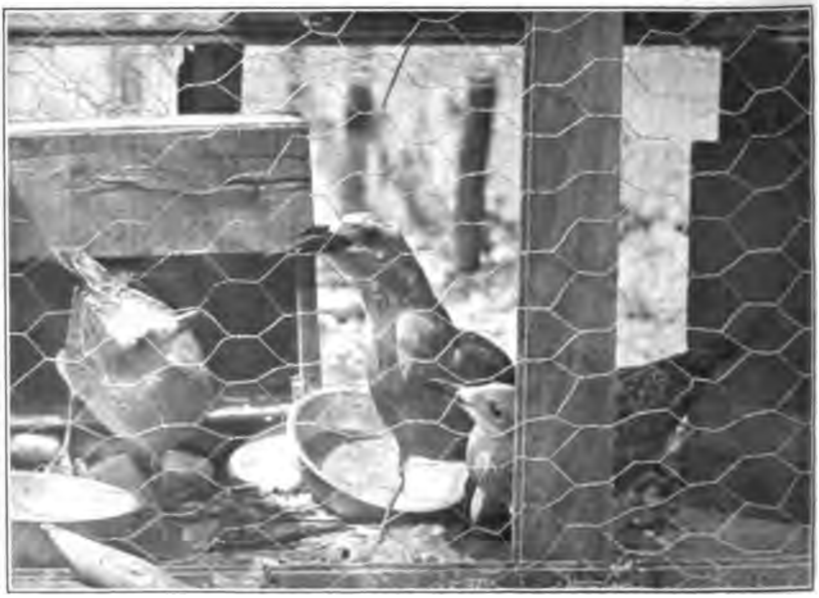
1. THE STRAWBERRY ISLANDS FROM THE EAST. ISLAND ON LEFT OCCUPIED BY GREAT BLUE HERONS; OTHER TWO ISLANDS BY HERRING GULLS.



2. GRAVEL ISLAND.



1. BLIND ERECTED ON MIDDLE STRAWBERRY ISLAND.



2. JUVENAL GULL SWALLOWING FISH ABOUT 10 INCHES LONG.

I had a tent made similar to that described by Sawyer,[1] with some modifications (pl. 2, fig. 1). For a description of this tent and for an account of methods and material employed, the reader is referred to the original paper in the Auk.

II. SOCIAL OR COMMUNITY RELATIONSHIPS.

Both juvenal and adult herring gulls seem to prefer the company of other individuals of their age. My captive gulls and those I have seen wild are usually to be found in close groups, especially when at rest. However, they are often cruel to each other and like other animals will fight fiercely for food.

A large amount of fighting occurs at a breeding place where no struggle for food is involved. Some of the encounters are undoubtedly the results of intrusions upon a nesting precinct, as is Herrick's opinion, and I saw adults resenting attacks upon the young by other adults. Many of the fights, however, seem to indicate simple belligerency. A gull will approach another with head somewhat lowered and bill pointed straight forward or slightly upward. They will then grasp each other by the mandibles and attempt to drag each other about. Blows may be given with the wings and even with the feet. In plate 3, figure 1, such an encounter appears. The gull on the right is shown just at the moment when its wings have struck its opponent. The heads of the combatants appear in an oblique position as a consequence of the locking of mandibles. Frequently other gulls will join in the fracas and quite a lively but usually short and harmless tussle follows. I saw one fight broken up by another bird interfering much as a rooster may interfere in an encounter between two other cocks. Often a challenge to fight is not accepted, and the bird approached simply retreats.

Various writers have mentioned the killing of young gulls by adults. According to Ward[2] this may be a very common occurrence.

Maltreatment of the young has also been described by Dutcher and Baily[3] and it has been discussed by Herrick.[4] I found that similar treatment was administered to a juvenal gull when it was placed in a cage with two juvenals 2 to 3 weeks older. One gull, the youngest of the three in the cage, was particularly persistent and savage in its attacks, so that I had to remove the newcomer until its head had healed and it was better able to defend itself.

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[1] Sawyer, E. J., A special bird blind: Bird Lore, vol. 11, No. 2, March–April, 1909, pp. 71–73. One page of text figures.

[2] Ward, H. L., Why do herring gulls kill their young. Science, n. s., vol. 24, 1906, No. 619, pp. 593–594.

[3] Dutcher, W., and Baily, W. L., A contribution to the life history of the herring gull (*Larus argentatus*) in the United States: Auk. vol. 20, 1903, No. 4, pp. 417–31, pls. 21, 22.

[4] Herrick, F. H., 1909, Organization of the gull community: Proc. Seventh International Zool. Congress, Boston, 1907.

On erecting my tent at one of the Sister Islands, July 12, 1911, I took a downy juvenal not more than a week old inside with me. This I released at 12.50 p. m., and it made its way out at once. Its appearance outside caused great excitement. The little gull started west in the direction of the place where I had captured it. On its way it went near a couple of gulls which appeared to belong to a nest I had under observation. These birds started the "challenge cry," and others joined in the same performance. The small gull approached the two adults just mentioned and was pecked on the head after a minute or so. It was next given a number of sharp blows which apparently did no serious damage. The little bird turned at bay and when pecked most severely ran screaming with mouth open toward its persecutors. This was followed by alternate running and fighting, a procedure which was successful in preventing further serious attacks. The bird eventually found shelter under driftwood about 50 feet away from my tent.

Herrick explains these attacks upon the young as follows:

> This is due to the ferocity of the guarding and fighting instincts in the old birds, and to a lack of attunement in the instincts of the young, in consequence of which a chick will occasionally stray from its own preserve and trespass on the domain of a neighbor.

Undoubtedly this covers many and perhaps most cases, but it seems doubtful whether the deaths among the juvenals at Gravel Island, described by Ward, can be explained as easily. There both Ward[1] and I found a promiscuous herding of juvenals without regard to precincts, at least when the birds were of good size. Furthermore, it does not account for attacks upon juvenals by other juvenals.

Other birds may nest in apparent safety upon an island even fairly densely populated with gulls. Spotted sandpipers, bronzed grackles, song sparrows, and other land birds were more or less common nesters on the Strawberry Islands. I found red-breasted mergansers nesting on all of the wooded islands occupied by gulls. So far as I could see, no attention was paid to these birds by the gulls. On the other hand, a large bird like the great blue heron seemed to be viewed with disfavor, and I did not find both occupying the same island. On one occasion, I saw a great blue heron pursued and much harassed by gulls.

I have always found herring gulls nesting on islands not inhabited by man, but exceptions occur in the literature. A very large colony of gulls studied by Dutcher and Baily was found nesting on Great Duck Island which has a lighthouse.

Though the herring gull seems to prefer remote places for nesting, it is a matter of common observation that at other times, if unmolested, it does not hesitate to frequent large cities where bodies of water with food occur.

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[1] Ward, H. L., Notes of the herring gull and the Caspian tern: Bull. Wisconsin Nat. Hist. Soc., vol. 4, *No. 4, 1906, pp.* 113-134, 2 plates.

III. FEEDING HABITS.

The herring gull is generally recognized to be almost omnivorous in its feeding habits. It is especially known and prized as a scavenger. I have found that fishermen appreciate its habit of ridding the water of dead fish. It has been my observation that fish, especially when fresh, are preferred by gulls; but when hungry they take almost anything in the animal-food line and many forms of plant matter. Dutcher[1] mentions insects including large numbers of ants as eaten by herring gulls. Eifrig[2] noted the occurrence of shells, seeds, berries, and a crab in the stomachs of three adult herring gulls taken May 29, June 10, and June 15. According to Knight,[3] sea urchins and starfishes are eaten. Various mollusks and a crustacean are mentioned by Norton,[4] and Audubon[5] states that eggs are sucked. There is even a record of the capture by a gull of a bat[6] which had been flying about over a river where gulls occurred. Various mollusks are mentioned by Mackay as gull food.

My captive gulls when very hungry would eat bread, but they preferred animal food. Their main article of food was liver with occasional feedings of fish scraps. When live fish are caught, the herring gull may immerse its head and a large portion of its body, but I have never seen complete immersion. The bird may fly down to the water for food, but it does not dive vertically as terns do. Other writers have made similar observations.

Pieces of food not too large are swallowed entire, and the mass may be relatively great (pl. 2, fig. 2). My captive gulls swallowed fish as long as 10 inches on a number of occasions. Under ordinary conditions in cool weather, one of my birds would eat 4 to 6 ounces of beef liver at a meal, when fed once a day, and it would be hungry the next day.

IV. BREEDING HABITS.

The nests, as has been stated by others, are usually fairly bulky and of varying materials. Apparently grass, fine weed stems, and feathers are preferred as these occurred in the majority of nests. Sometimes, however, nests were made largely of strips of bark or of coarse weed stems. Other beach débris may be used, especially the finer or softer materials. Bits of bark and other coarse materials appear in the nest which is shown in plate 4.

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[1] Dutcher, W., Report of the committee on bird protection. Auk, vol. 21, 1904, No. 1, pp. 164–165.

[2] Eifrig, C. W. S., Notes on northern birds. Auk, vol. 23, 1906, No. 3, pp. 313–318.

[3] Knight, O. W., The birds of Maine. 1908, p. 49.

[4] Norton, A. H., The food of several Maine water birds. Auk, 1909, vol. 24, No. 4, p. 438.

[5] Audubon, J. J., Ornithological biography. Edinburgh, 1835, vol. 3, p. 591.

[6] Rodger, A. M., Herring gull (*Larus argentatus*) capturing a bat. Ann. Scott. Nat. Hist. Soc., 1903, p. 51.

As has already been stated in the introduction to this paper, a great variety of locations may be chosen for the nest. In general, it seems that uninhabited islands are preferred, where the nest may be anywhere on the beach or back some rods from the open beach in bushes, among tall herbaceous plants, or in grass, or upon rock ledges. Often the shelter of a drift log is chosen (pl. 5, fig. 2). Nests may be placed in trees under certain circumstances, a point that will be discussed elsewhere in this paper.

As the males can not be distinguished from females by their plumage, ordinarily, it is difficult to get data concerning the relative parts taken by the two parents in brooding. Dutcher and Baily[1] obtained evidence that both parents take part in brooding the eggs. Some observations were made by Dutcher and Baily[2] on the turning of the eggs by the brooding bird. They found that the eggs are sometimes turned slightly with the bill when the bird goes on the nest, though in one case where each egg had been marked with an arrow, only one was found turned after the bird went on the nest. I also obtained some evidence of the eggs being turned by the bird. In some cases, as the parent nestled down over the eggs it appeared probable that at least a slight turning of eggs would occur. There was usually more or less shifting of the feet, body, and plumage, as the bird adjusted itself to the eggs and nest. This performance has been described in detail by Dutcher and Baily.[2]

On very warm days, especially at midday, I found that the nest is left frequently for a few moments. At such times the bird goes to the water's edge and takes at least a partial bath. There is much splashing of water with the bill and sometimes with the whole head. There is some drinking of water also at this time.

So far as I could determine there is more or less brooding of the young for several hours after hatching or until they are able to run about. Often on a hot day one of the parents would simply stand over the newly hatched nestlings shading them from the sun (pl. 8, fig. 1). The other parent was usually near by, and it would change places with its mate at intervals.

I doubt whether there is much covering of the young for more than a day or two after hatching, in pleasant weather. No observations were made in bad weather of the treatment of very young birds. I obtained considerable evidence that both birds participate in feeding the young. According to Herrick,[3] the young gull receives its first food about one hour after hatching, at the nest.

The larger juvenals tease vigorously for food when hungry, and the whole feeding performance for a young gull more than a few days old has been well described by Ward.[4]

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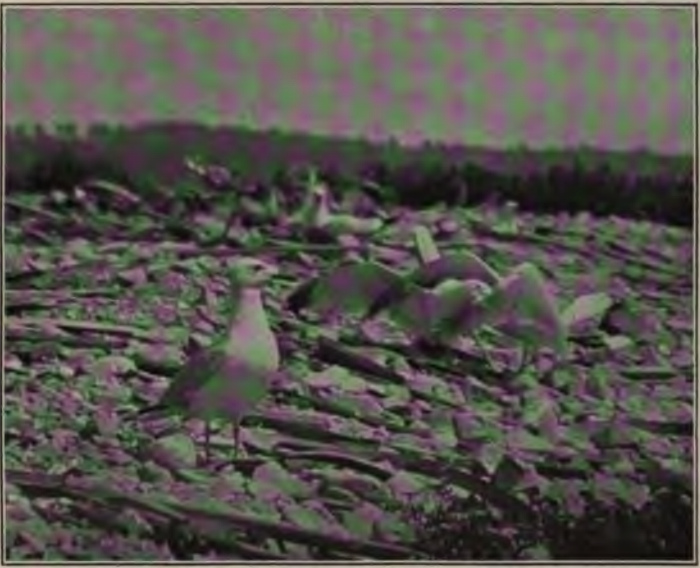
[1] Op. cit., p. 426.

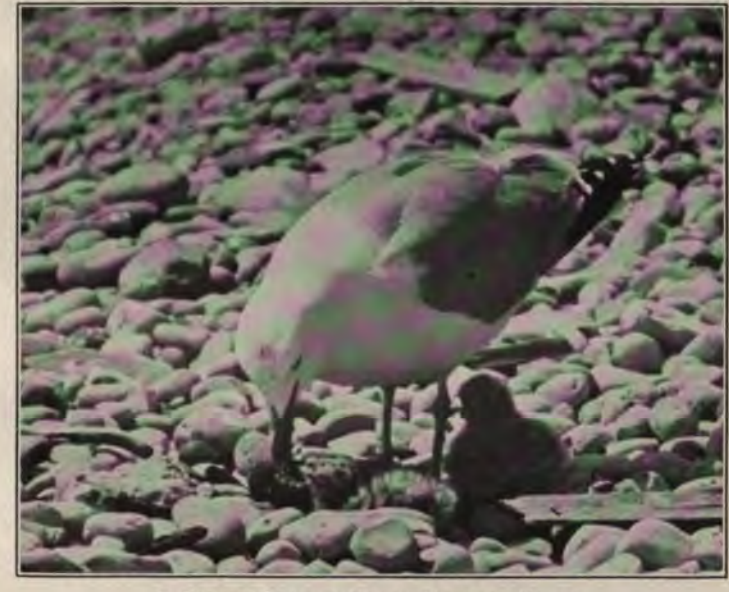
[2] Op. cit., p. 427.

[3] Internat. Zool. Congress Report, op. cit.

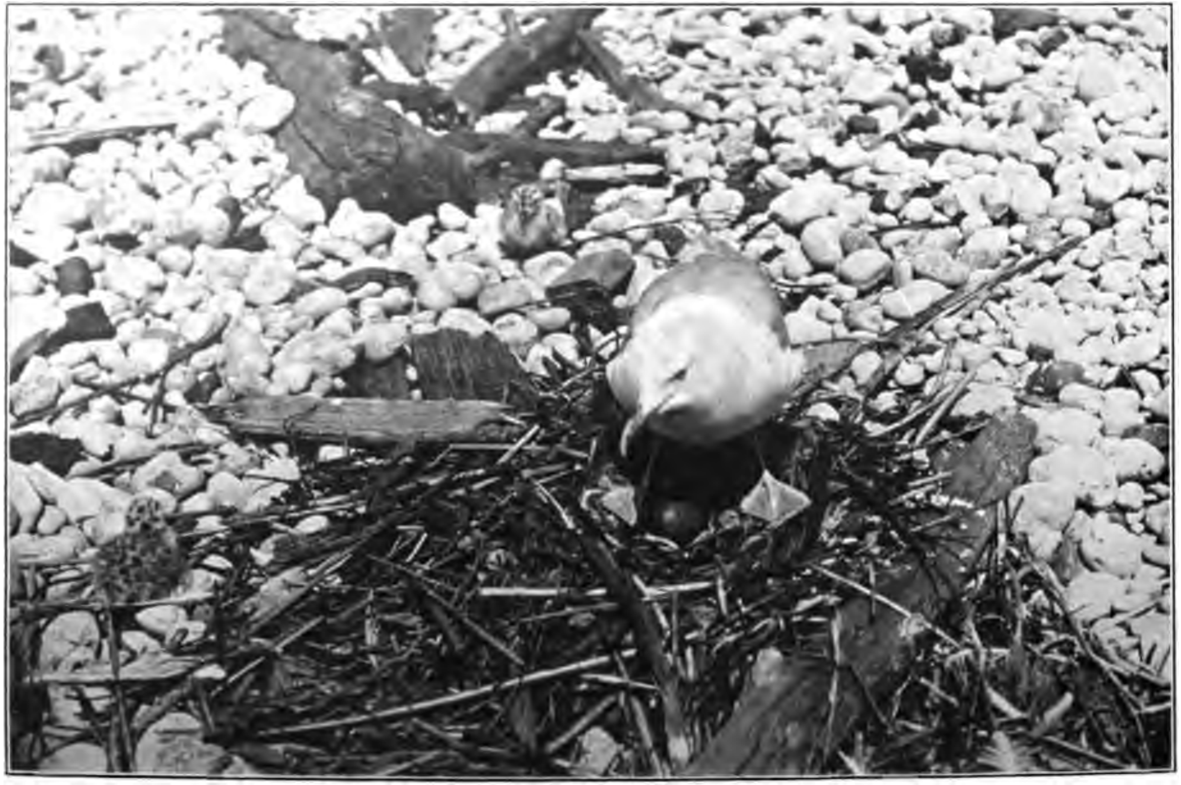
[4] Op. cit., p. 121.



1. HERRING GULLS FIGHTING.



2. PARENT FEEDING NEWLY HATCHED YOUNG.



HERRING GULL WITH NEWLY HATCHED YOUNG AT NEST ABOUT 6 FEET FROM BLIND. NOTE THE COARSE NEST MATERIALS.

The newly hatched young, according to my observations are more passive, and I obtained some evidence that the parent may initiate the feeding performance. Similar conditions occur in the feeding of young pigeons. On June 30, 1911, while taking observations on one of the Strawberry Islands, a pair of gulls whose nest was about 5 feet from the base of my tent fed two young not many hours old and still too weak to walk well, at irregular intervals within 8 to 10 feet from my point of observation. The little gulls had been coaxed away from their nest for a few feet by their parents, a distance which they covered with difficulty.

The following notes concerning the observations just mentioned have been taken from my notebook. The bird shading its young was relieved at 12.40 p. m., and went down to the water for a drink. The other parent at once proceeded to feed the young gulls while the first bird stood a few feet away at the edge of the water. The adult bird did not insert its bill in the mouth of its offspring, but the latter took food from the ground just below the bill of the parent. Occasionally the young reached up toward the bill of the parent, which was held low, often almost at the ground (pl. 3, fig. 2). A quantity of food in a fine and soft condition was disgorged in more or less of a heap. After the young had eaten, the parent swallowed what was left. These very young birds ate slowly, apparently without much appetite. The whole performance passed off quietly and with no rapid movements.

At 1.45 p. m. I saw the same young birds being fed again. A little later I noticed another feeding of some gulls a few days older. Small fishes appeared in the food disgorged by the parent.

In spite of the fact that the gulls seemed to settle down to normal activities during my tent work, I saw surprisingly few cases, relatively, of feeding the young. These were usually a little too far away to permit close observation, and it was seldom possible to determine by observation from my tent what the nature of the food was.

The stomachs of six young herring gulls "of different sizes" as reported by Norton,[1] "contained almost no fish, but all contained ants in varying quantities, only one being full."

Where many young gulls occur in a relatively small area, it is difficult to determine whether the adult birds always feed only their own young. The small amount of evidence I obtained suggested that the parents, usually, feed their own offspring. But it is of course possible that birds usually feeding their own offspring may occasionally give food to other juvenals.

At Gravel Island there was apparently considerable promiscuous feeding according to the observations of both Ward and myself.

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[1] Dutcher, W., Report of committee on bird protection. Auk, 1904, vol. 21, No. 1, p. 164.

I observed adult gulls alighting near close flocks of young birds on a number of occasions, at Gravel Island. Each time the juvenals surrounded the adult like a pack of wolves, and it was often completely hidden from my view by the struggling young gulls. In plate 7 such a scene appears. Such a performance was usually accompanied by considerable noise made by the hungry birds. Other adult birds sometimes added to the clamor by screaming. The general excitement is shown in the illustration just mentioned.

The period during which the young are fed is evidently a long one. I saw young birds which must have been at least 6 weeks old, and probably considerably older than this, still being fed by adult birds. It is of course possible that young birds may be obtaining some of their food themselves before all food giving by their parents or by other adults ceases.

On a few occasions, I saw adults apparently resenting the approach of other adults to their young, but data of this sort are very meager. These observations and those quoted in this paper from Herrick and Hornaday, however, make it probable that the young are guarded for at least a considerable time after hatching by their parents.

I have been unable to obtain data concerning the relationships of the parents to the young when the latter are learning to take care of and feed themselves. Adults and young roam about together in flocks for weeks or months after the young are able to fly.

V. GENERAL BEHAVIOR OF THE JUVENAL GULLS.

The behavior of the young just after hatching has been described by Ward.[1]

According to Dutcher and Baily,[2] "The instinct to hide seems to be present within an hour or two after hatching, or so soon as the young bird is strong enough to walk." My own experience is that the instinct to hide is not always developed thus early. On July 6, 1907, at Gull Island near Marquette, Mich., in Lake Superior, I found a nest containing one single nestling which stood up pertly in its nest and did not give the usual indications of fear (pl. 6, fig. 1). The plumage of this bird was dry, and it was able to stand. On the same day, another nest was observed with two young and an egg in which the occupant was breaking its way out (pl. 6, fig. 2). In this case the two nestlings showed very great fear and left their nest which was located on a small ledge of rock, squealing pitifully. They showed other signs of distress and began to pant. Mrs. Strong held an umbrella over the birds to protect them from the intense sunlight that prevailed. Nevertheless, before I had gone through the process of mounting a camera on a tripod and making one exposure, one of

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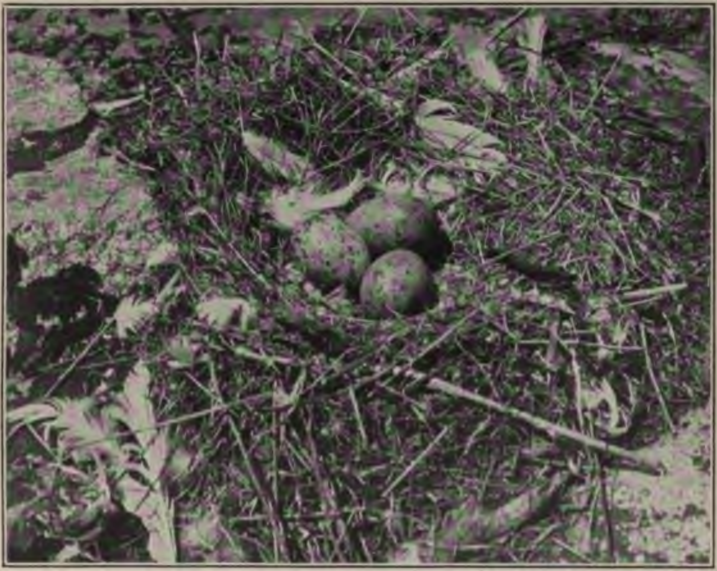
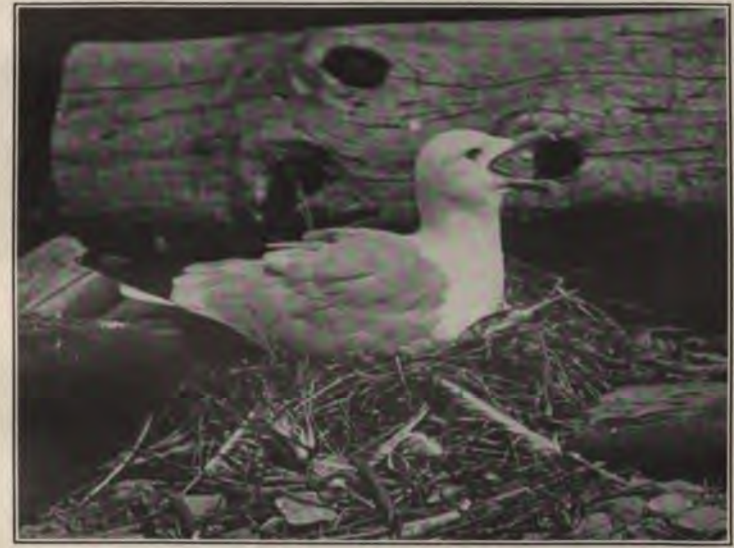
[1] Op. cit., p. 120.

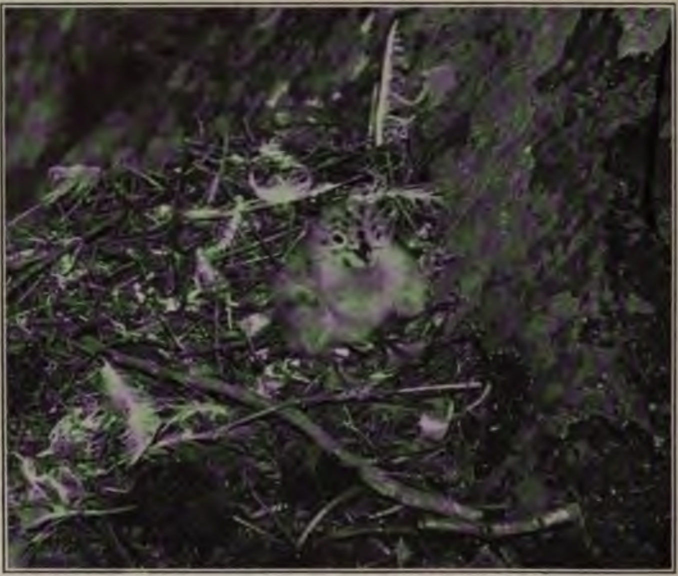
[2] Op. cit., p. 422.



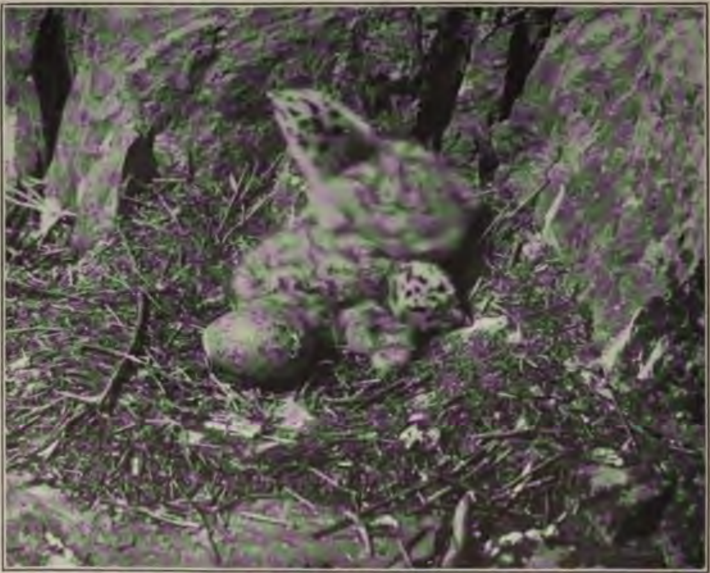
1. CHARACTERISTIC GULL NEST ON ROCK LEDGE AT GULL ISLAND, NEAR MARQUETTE, MICH., IN LAKE SUPERIOR.



2. HERRING GULL ON NEST.



1. NEWLY HATCHED YOUNG SHOWING NO FEAR.



2. NEWLY HATCHED YOUNG IN A PANIC OF FEAR.

these birds died. Presumably the combination of fear and heat was responsible. The dying bird appears in the picture.

I agree with Dutcher and Baily that young gulls show the hiding instinct as soon as they are able to run about freely. During the pandemonium that prevails among the adults when one approaches the nesting place of a colony of gulls, the larger young not yet able to fly may be observed with the aid of strong glasses, running about to find places for hiding. On reaching shore all young birds able to leave their nests will be found hiding except those that have taken to the water. Those able to fly are pretty sure to join the adults in flying overhead, or they often alight on the water at some distance. This hiding instinct has been described in some detail by Dutcher and Baily.

At Gull Island in Lake Superior, I frequently saw half-grown gulls running headlong over the rocky surface of the island after being dislodged from their hiding places. They would often fall 10 or more feet over ledges to rocks below without any apparent injury or significant delay in their rush for the water.

According to my observations the young gull, when attempting to hide, especially if still in the down plumage, will remain perfectly quiet until it is handled or removed from its hiding place. After being disturbed in this way, however, the hiding instinct seems to be replaced by an impulse to flee and the bird, if not checked, will run in headlong fashion until it reaches water or gains a position where it is really out of sight, a number of rods away. Usually when such a bird reaches the water it will swim some distance from shore. I have observed the same behavior in the young of the Wilson's and roseate terns, *Sterna hirundo*, and *S. dougalli*. The laughing gull (*Larus atricilla*) apparently shows the same behavior, but I have not studied the habits of this species enough to make a complete comparison. Probably this hiding behavior is common to most species of the whole order, under similar circumstances.

In the case of the gulls hatched in tree nests, the behavior must of course be different. It is hardly conceivable that the young in tree nests as high as 50 feet above the ground, as some have been stated to be, can leave their nests before the flight feathers are well developed. Concerning this point we find Dutcher and Baily[1] saying:

> The young in tree nests also seem to have sense enough not to walk off the edge of the nest, for in 1902 Mr. Baily found young at least 10 days old in a tree nest.

As viewed from my tent, the young gulls appeared to spend most of their time standing idly about waiting for food. The recently-hatched birds were observed enjoying the shade of one of their parents when the sun was intense as has already been stated in this paper. They also used driftwood or anything else offering shade. The more developed juvenals, especially on warm days, did a large amount of bathing at the water's edge. Still older young would swim farther out from shore in bathing. When the definitive feathers are developing and begin to burst from their sheaths, much time is spent in dressing the plumage with the beak. Whether the opening of the feathers is facilitated by the feather manipulation could not be determined.

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[1] Op. cit., p. 422.

VI. DEVELOPMENT AFTER HATCHING.

A detailed account of the hatching and early development of the young after hatching has been given by Dutcher and Baily.[1]

Growth is rapid, but the young are in the down plumage for a number of days after hatching. It is not in the province of this paper to give a detailed description of the plumage, and the reader is referred to the account given by Dutcher and Baily[2] (p. 422 with pl. 22). The sequence of plumages has been described by Dwight.[3] The dark plumage of the juvenal gull is replaced after the first winter by a lighter and less mottled plumage with quite a bit of individual variation in the rate of change, judging from my captive gulls. At two years, my gulls had lost most of their juvenal coloration. Strange to say a wild gull obtained in the winter of what must have been its second year, was somewhat behind the others when they were 2 years old. None of my gulls had acquired at two years as advanced a plumage as that described by Dwight for herring gulls of that age. Sharpe[4] describes progressive changes extending through the first five autumns, and he says that the "quills" have more dark coloring at the fifth autumn than appears in older birds. The following quotation from Townsend's account of the herring gull agrees well with my observations:

> It is superficially evident from the large number of dark and mottled birds at all seasons, that it takes several years to attain the beautiful adult plumage. What appears to be a dark tip to the tail, so prominent in young birds of a certain age, is often retained after increasing whiteness has set the stamp of years, but it is entirely absent in the snowy white tail of the fully matured bird. Birds with pure white tails with the exception of a slight central sprinkling of dusky brown and with a few faint gray streaks in the upper breast, are not uncommon.

My gulls acquired a yellow iris in the second winter, but in their third fall they still had the bill colored as in the first year. According to Astley,[5] the bill does not become yellow until the fourth year, although a nearly complete adult plumage appears at the third autumnal molt. Sharpe's account indicates that the adult coloration of the beak is not acquired until after the fourth autumn.

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[1] Op. cit., pp. 421–422.

[2] Op. cit., p. 422.

[3] Dwight, J., The sequence of plumages of the Laridae (gulls and terns): Auk, 1901, vol. 18, No. 1, pp. 49–63.

[4] Sharpe, R. B., Catalogue of birds in the British Museum. Vol. 25, 1896, p. 264.

[5] *Astley, H. D.*, My birds in freedom and captivity, p. 160. E. P. Dutton & Co., London, New York, *J. M. Dent & Co.*

[NOTE.—The following observations were made too late to appear in the paper published in the Auk:

The bills of the gulls obtained at Ephraim changed to the adult yellow toward the end of their third year. By April 12, 1914, the bills of both birds had acquired a pale-yellow color. By May 3 the yellow had become as rich as that of the adult, but the black subterminal spot still remained. On May 13 I noted that the adult orange color of this spot was to be seen distinctly at the proximal margin.

Both birds had lost most of their mottled plumage during the preceding two months and at a distance appeared almost entirely adult in color, though the white portion of the plumage still contained many dark gray flecks. During this period, the birds became more adult in behavior, and during the latter part of it the "challenge" cry developed rapidly. The notes of the alarm cry also appeared for the first time. Another gull of the same age which had been in bad health for several months made no progress in color or behavior.

Further observations were ended a few days later when a marauder broke into the gull yard and released my birds.]

Very meager data are available as to when breeding begins. A case is described by Dutcher[1] of a gull which apparently began breeding when two years old.

It is my judgment that herring gulls rarely breed this early. I saw a few with a very small amount of the immature coloration in their plumage, which were certainly at least 2 years old. I obtained no evidence that these birds were breeding except the fact of their occurrence with breeding birds at a breeding place. All of the birds that I actually saw with eggs or young were adult, as far as I could see.

I have seen relatively few immature gulls during the spring and summer after their first winter, but this is probably due to their scattered distribution. Many individuals linger some distance south of the breeding range of the species. Thus Townsend speaks of immature gulls being abundant at all seasons off the coast of Essex County, Mass., though herring gulls do not now breed south of Maine on the New England coast. Immature gulls are also seen over the south portion of Lake Michigan during the breeding season, though the nearest breeding place is many miles to the north.

Concerning the longevity of the herring gull, I have found two records which indicate that the period of life may be considerable, though giving no idea how long it may be. Thus Morris[2] mentions a herring gull which was being fed daily and was very tame. This bird is stated to have escaped 30 years before "from a garden where he had been a prisoner." Another bird known as "Gull Dick" is well known to ornithologists through the reports made by Mackay to The Auk. He says that this bird[1] had "the habit of frequenting and returning year after year to the waters adjacent to Brenton's Reef, Narragansett Bay, and was known in consequence to the crew of the lightship anchored in that locality.

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[1] Dutcher, W., Results of special protection to gulls and terns obtained through the Thayer fund: Auk, vol. 18, 1901, No. 1, p. 98.

[2] Morris, F. O., A history of British birds. Vol. 6, p. 159.

In 1891 the bird arrived October 12, which makes the twentieth winter it is known to have passed in this locality. This bird was identified each year partly by its tameness, and "also by certain marks on its wings, also by its cry." It was reported by Mackay during the following four years, after which it failed to appear.

VII. VOICE.

1. *Introductory.*—During the summer of 1911, especially, I gave a large amount of attention to the sounds made by the gulls with the hope of making interpretations concerning their significance. Attempts to describe the various vocal performances were made, whenever possible, with difficulties which will be appreciated by all observers who have tried to make descriptions of animal sounds.

Though I tried to notice anything that might have any bearing on the significance of the sounds made by the gulls, I had the following points especially in view: (1) The circumstances under which each sound was made; (2) any possible evidence of associated emotions; (3) the attention given by other individuals and especially by the young to these sounds. As all of the cries occupy only a few seconds at the most, it is necessary when in the field to be ready to give instant attention the moment the sound is heard. Here again we see the advantage of the presence of a considerable number of individuals at such close range as they can be at a breeding place. Some notes are not made frequently by a single individual, and the chances of hearing them are multiplied many times when the observer is in the midst of a fairly large breeding colony. On the other hand, of course, a large number of gulls in a limited area make a bedlam of noise which is often confusing. With careful concentration on single sounds or performances it is possible to reduce the confusion of sound to a working basis.

2. *The alarm cry.*—In my experience, whenever wild gulls are disturbed at their breeding places, at least by man, they become very noisy. Though other sounds are made, the characteristic and usual cry is what has been called by Herrick,[2] Ward, and others the "alarm

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[1] Mackay, G. H., Habits of the American herring gull (*Larus argentatus smithsonianus*): Auk, vol. 9, 1892, No. 3, pp. 221-228.

[2] Herrick, F. H., The home life of wild birds.

cry." This consists of sharp and short notes in doublets or triplets which are produced with great variations in quality and in pitch. I was unable to determine whether these variations are produced by different individuals. They are striking and always to be noted when a colony of breeding gulls is disturbed.

After trying various syllables to represent these sounds, I finally decided that the following is as satisfactory as anything I could devise, kek′-kek-kek, with an accent on the first syllable, the "e" being sounded as in deck. Often only two instead of three of these sounds are made in a group. These triplets or doublets are uttered in rapid succession as the bird flies about in the general panic.

Mackay[1] described the alarm cry with the syllables "cack, cack, cack," and Herrick[2] used the following: "waw-wak-wak! wak-wak! wak-wak!" Ward used the same symbols in his paper. Another rendering was made by Knight[3] as follows: "ha-ha-ha" or another alarm cry as follows: "qu-e-e-e-a-h que-e-e-e-a-h."

The alarm cry may be high and shrill or rather low with "chest tone" quality. Intermediate variations also occur. As the disturbance in a gull colony subsides, these notes are uttered less and less frequently, and the lower notes predominate more as the excitement decreases. The cries also become less loud and incisive, until, as Herrick[4] has expressed it, "Finally ceasing like a clock running down, the mandibles continue to work with no sound for a moment or so."

I have often heard these sounds made when the birds were apparently simply solicitous or slightly anxious concerning their eggs or young. Thus hours after the gulls had settled down to apparently normal activities about my tent, single birds would occasionally fly overhead making the alarm cry. At such times the cry is characteristically low and not at all shrill.

3. *The "challenge."*—This was for me the most interesting vocal performance, though it is less often mentioned by other writers. Herrick describes a "scream of defiance" and has a photo showing a bird making this noise. Ward is the only writer to my knowledge who has described this performance in any detail, and his interesting account follows.[5]

> Frequently, the general clamor would be dominated by a peculiar cry which I put into words as "yeh, yeh, yeh," rapidly repeated and increasing in vehemence to the utmost capabilities of the gull, when it quickly ceased. Usually, a few seconds after one began another joined, until often there were a half dozen birds screeching at once, and occasionally, this number would be increased to a score or more * * * The bird stretches its neck downward, opens its bill widely and begins the call, then with a jerky sort of start it stiffly raises its outstretched neck, usually to an angle of about 45°. Generally, almost invariably, the head, neck, body and tail are all held

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[1] Op. cit., p. 226.

[2] Op. cit., p. 55.

[3] Knight, O. W., op. cit., p. 48.

[4] Op. cit., p. 55.

[5] Op. cit., p. 130.

> in practically the same line and in a remarkably stiff manner. The whole performance is so machinelike in its rigidity and precision of motion that the gulls appear like a lot of automatons.

I have adopted Ward's term "the challenge" for this cry.

I made a number of records of the performance, and I add a few details to Ward's description. Just before the head is raised a single note which may be of appreciable duration is often made. This I tried to represent in my notes by the syllable "*kēēē.*" It is followed by a series of high and shrill notes as described by Ward. I finally settled on the following representation in my notes: "kēēē, kēē′ ek, kēē′ ek, kēē′ ek, kēē, ek, kēē′ ek, etc." The e in kēē is sounded as in see and this syllable is accented. The first note is longer. Although this noise seemed to take more time, I found on using a watch that it occupies only a few seconds. The performance, may, however, be repeated more than once during the course of a few minutes, when other gulls are "challenging."

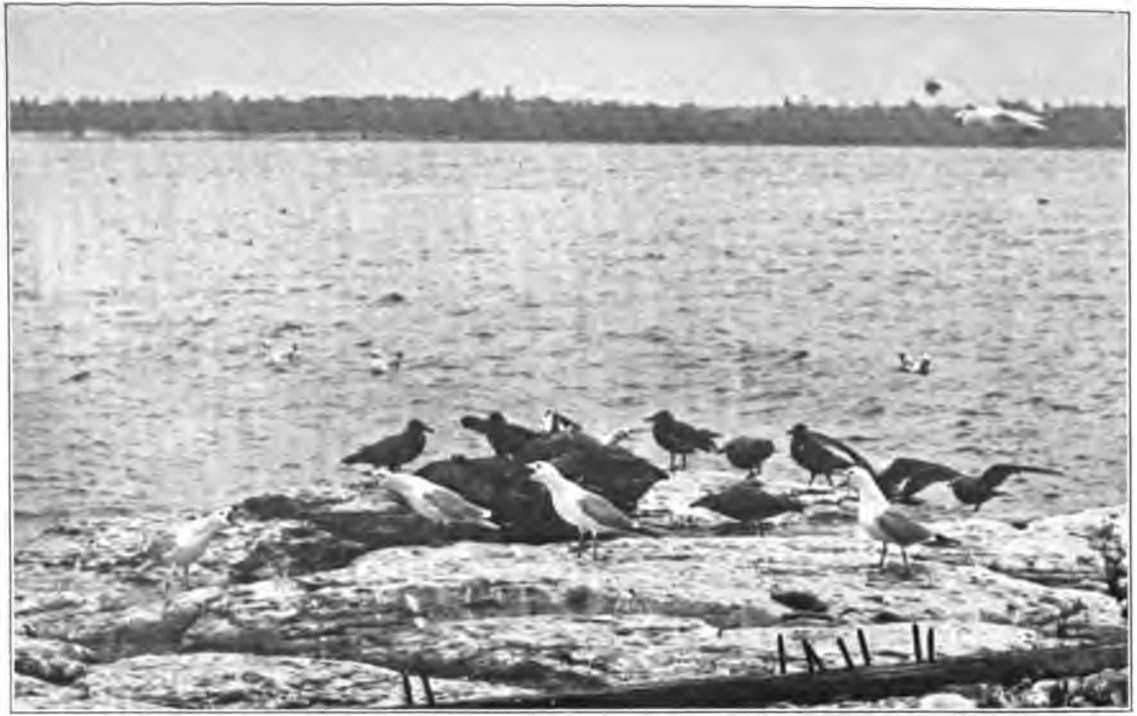
In my experience the "challenge" call is usually made by a bird on or about the ground, but I have often heard swimming or flying birds make this noise. All of these situations are shown in plate 7, where a number of birds are seen in the performance. The three birds on land at the left and in front give the best idea of the usual position.

Good pictures of gulls indulging in the "challenge" appear in both Herrick's and Ward's accounts of the habits of these birds.

Concerning the significance of the "challenge" performance, little more than opinions can be offered. It may sometimes be made when other individuals are frantically indulging in the "alarm cry." I have noted individuals going through this performance while flying about in the general panic which took place when I was landing at an island where gulls were breeding. This behavior often seems to indicate a belligerent attitude and it then well deserves the term "defiance cry" or "challenge." My observations lead me to agree with Ward in saying:

> Anything that startles the gull without producing a panic, or the proximity of fighting birds, or even at times the approach of other gulls seems to be sufficient cause for its production.

The first efforts by my captive gulls at "challenging" were made in their first autumn. The same positions were taken, and the sounds made were as similar as the first crowing efforts of a young rooster are to the crow of a mature cock. Each time the performance, which occurred only a few times in my presence until the spring of 1914, was begun without warning, and it was over in a few seconds. On each occasion a contest over food was in progress, although the bird making the noise was not always engaged in the struggle. Contests over food are exceedingly frequent, however, and the usual sounds



Gull Scene at Gravel Island. The Dark Birds are in Juvenal Plumage. An Adult with Food is Hidden by the Juvenals. The other Adults are Making the "Challenge Cry."

1. PARENT GULL SHADING NEWLY HATCHED YOUNG.

2. GULL AT RIGHT MAKING THE "MEW" CRY, VERY YOUNG OFFSPRING WALKING JUST *BEHIND.* OTHER GULLS SEEN IN CHARACTERISTIC LOAFING POSITIONS.

made, with these rare exceptions, consisted of a shrill squealing chatter.

Adult birds in late summer after the breeding season is over make a cry which is at least similar if not identical with the "challenge," but I have not observed it at close range.

4. *Other cries.*—Though the "alarm" and "challenge" cries make up a large portion of the general clamor at a breeding place, especially when the birds are disturbed or excited, other sounds are also made. Of these a cry remarkably like the mewing of a cat is one of the most frequent. The birds I saw "mewing" held the neck arched and the head pointed downward. This performance often occurred when adults approached young birds apparently their offspring. It also seemed at times to be made in calling the young. The adult gull at the extreme right in plate 8, figure 2, is seen "mewing." This bird was engaged in coaxing its newly hatched young to a place not so near the tent, and they were too weak to do more than stumble along over the pebbly beach. The whole procedure was rather deliberate and more or less interrupted. Now and then the adult would make the mewing sound, and on one of these occasions I obtained the photograph just mentioned. Ward[1] observed another set of conditions under which the mewing cry may occur as follows:

> The first day that I was in the tent, at 3 p. m., a rain squall came up. Dark clouds obscured the sun, occasional flashings of lightning were seen, and peals of thunder sounded from time to time. The wind came in cold sharp gusts. The shrill cries of the gulls were quickly subdued and a plaintive mewing was the all-prevailing sound.

On a few occasions I heard a shrill and prolonged cry which was distinguishable from the mew and yet apparently related to it in its characteristics. This I have represented in my notes by the syllable "kerr" with the "e" sounded as in her. It suggested to me a noise often made by a contented hen in the chicken yard. I was unable to get any clue to its significance.

A high-pitched kee sound is often made when the bird is flying. I have heard this given by gulls away from their breeding place. It is of appreciable duration, and it descends slightly in pitch.

Another performance which I noted only a few times involved a rapid series of weak notes not unlike the peeps of a newly hatched gull but with more of a whispering quality. This I represented as follows: "peep-peep-peep-peep-peep, etc." The beak was opened only slightly and shut with each note. It is possible that this is the "run down" alarm cry which Herrick mentions, but its occurrence was not connected with any apparent alarm nor was it closely preceded by alarm cries. The bird stood about in the position shown in plate 8, figure 1, and was very near my tent. The noise would not have been heard if the gull had been many feet away. Perhaps a fair guess would be to suggest that we had here an incipient alarm cry which did not involve a stimulus strong enough to produce the full response.

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[1] Op. cit., p. 129.

Young herring gulls give a cry for food which varies with age. The newly hatched birds utter only weak peeps. As they grow older these develop into more insistent squealing notes which may be made with a bowing motion for each. When attacked or in distress, juvenal gulls often make a sharp and still more incisive squeal in which the notes are uttered more rapidly and more loudly. I have already mentioned the attempts at a challenge cry which are made by juvenals.

VIII. REACTIONS TO STIMULI.

1. *Auditory.*—I know of no experimental work on the reactions of gulls to sound stimuli, but I have made numerous observations in the field and with my captive gulls which show that hearing is reasonably keen in these birds, especially under certain circumstances. The bird shown in plate 5, figure 2, was easily startled during the earlier part of my tent studies by the small though sharp noises made by the shutters of my cameras. During the course of the day this gull became less and less sensitive to such noises and to other slight sounds which came from my tent, though one end of the tent was hardly 5 feet away. The responses finally consisted of little more than short turns of the head. A pistol shot from a boat fully a quarter mile away from shore caused a wild panic on the island. Little attention had been given to the boat before the shot was fired and boats could come nearer without causing a disturbance so long as no shooting occurred.

On another occasion the sharp noise made by a falling timber on the beach caused great alarm among gulls which could hardly have seen the fall. Great excitement was caused during the night of my stay on one of the Strawberry Islands by the noise produced by a falling board which was blown down from a position against my tent. It is improbable that many gulls if any could have seen this board fall. The resemblance of such noises to that made by the firing of a gun undoubtedly explains the intensity of the reactions. Many and perhaps all of the adult gulls had learned the significance of a gun shot.

My captive gulls when tested by some simple experiments on September 27 and 29, 1913, were not much disturbed by any noises which I made out of their sight, though they responded to various sharp sounds or to a sudden shrill whistle by quick turns of the head.

2. *Visual reactions.*—Like practically almost all birds the herring gull is predominantly visual in its behavior. It also appears to be unusually alert to visual stimuli. Rapid movements, especially,

are noticed as is the case with most seeing animals, so far as we know anything of their reactions to visual stimuli.

Standing outside of my tent, I could distinguish the form of a man inside through the thin tent cloth, in certain positions with reference to the sun's rays. Small portions of the man's figure were also visible to me through narrow openings at the corners of the tent. It does not seem probable to me that the gulls could fail at least occasionally to get such glimpses for they often came within a few feet of the tent and it was evidently under constant scrutiny. Nevertheless, neither the gulls nor any other birds appeared to notice these evidences of the presence of a man inside. The visual images afforded under such circumstances were of course of very low light intensity and of vague outline. They were also very incomplete and often only small portions of a human form would be even faintly visible. At any rate they seemed to lack the intensity or completeness necessary for arousing the associations connected with the appearance of a man in the open.

On the other hand, I obtained some interesting evidences of sensitiveness to very small visual stimuli under other circumstances. In the course of my tent studies, I found a need for new openings before the series of apertures which appears in plate 2, figure 1, had been prepared. A large pocket knife blade was used for the purpose, and the cloth was cut cautiously. On two occasions the knife blade slipped through the cloth, unexpectedly, exposing a large portion of its length. These occurrences were the causes of small panics among a number of the gulls in the vicinity. The appearance of a small portion of my hand through one of the corner openings caused considerable excitement even when no rapid movements were involved.

I used my cameras, however, at the openings with considerable freedom after the first hour or so of quiet watching inside the tent. The lens was often pushed partly through an opening without arousing any significant disturbance. It was a dark object and it was moved slowly, whereas the shining steel of the knife blade came into view suddenly.

In spite of the failure of the gulls to be disturbed by possible glimpses of the man inside the tent, there is abundant evidence that these birds see unusually well, as compared with most birds, in weak light. As will be discussed in the section of this paper which deals with the nocturnal activities of gulls, these birds are often active at night. My captive gulls if very hungry would eat in considerable darkness when their food was placed in a customary position, even when it was not easy for me to make out more than the bare outlines of the pieces of food. Thus on May 3, 1913, I fed my gulls at about 8 p. m. The sky was clouded, and there was barely enough light to follow the movements of the birds from a position about 15 feet away. The birds, which were thoroughly hungry, moved about somewhat uncertainly but they fed promptly from the two dishes in which their food was placed. When these birds were still partly in the nestling down plumage, on the evening of July 8, 1911, I made some notes on their movements at night. There was some light from the moon which was at half phase. I found the birds swimming or standing at the edge of the water in their inclosure, and they seemed to move easily in the semidarkness.

During even the darker portion of the night that I spent on Middle Strawberry Island, I had plenty of auditory evidence that both adult and young gulls were more or less active when it was too dark for me to see any thing of the birds. The moon set about 1 a. m., and there was no light except that furnished by the stars. Adult birds were evidently flying occasionally, and juvenals were occasionally heard peeping.

On many occasions, food was brought to my captive gulls in paper wrappers. Often the package was placed on the ground more or less completely open. When the paper was flapped by wind, the gulls showed a good deal of apprehension. At one time they would not approach the package, although they could see that food was inside. They became more accustomed to the flapping paper but did not entirely lose their fear of it. This experiment was attempted only occasionally.

Even when there was no flapping paper, great distrust was shown for the package, when the contents were covered by it though not entirely hidden. Under such circumstances, food was removed with slow and timid approaches followed by quick retreats. Flapping pieces of paper were for over a year very disturbing to the captive gulls, but after they had been fed daily for some weeks with food placed on a sheet of paper, their fear of moving paper decreased greatly.

3. *Reactions to chemical stimuli.*—During considerable portions of the time that I had the captive gulls, I conducted experiments on their reactions to chemical stimuli. A preliminary statement[1] concerning the results of this work has already been published, and I plan to publish another fuller account later. In general, I may say here that I found my captive gulls showing what I interpret as a dislike for pieces of liver that had been dipped in solutions of table salt or in weak acids. The following notes are extracted from my records of the first experiment. On July 11, 1911, I placed a number of pieces of herring in a strong solution of table salt in a

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[1] Strong, R. M., 1912, The sense of taste in birds: Science, n. s., vol. 35, No. 911, June 14, p. 940.

pan just before feeding the gulls. Another pan contained similar pieces of herring without any salt. The birds were very hungry, not having been fed since the previous evening. All three birds showed great aversion for the salted fish. Two ate of the salted food at once and the other joined them in a moment. The response was immediate, one bird disgorging what it had swallowed. Another dropped what it had taken, and the third swallowed only one piece. All three birds ran to water in less than a minute and drank heartily, though they had taken very little of the solution. They did not return to the food during 20 minutes that I waited. Experiments with other materials were carried on after this until September 6, 1911, when a 10 per cent solution of sodium chloride was employed. Pieces of liver were placed in the solution. The birds were exceedingly hungry and ate voraciously, paying no attention to the salt solution. On September 23 a 20 per cent solution of common table salt was tried with pieces of liver. The birds were not so hungry at this time. One went to the dish containing the salt solution and picked up a piece of liver with the tip of its beak. After a few minutes of cautious manipulation of the liver it was taken into the bird's mouth, only to be hurriedly ejected. The gull at once jumped into the swimming tank and drank water, washing its beak vigorously. The other gulls did not take any food on this occasion while I was present. Later, similar reactions were obtained with weaker solutions of table salt and also with weak acids. Food was often rejected, even when the taste was just perceptible to me under the conditions of the experiments.

So far I have almost no significant results with bitter and sweet solutions, although a great many tests have been attempted. This has been surprising to me, as results were obtained readily with chicks and ducklings for the same solutions, with food, however, which would hold more of the solution.

The point of greatest interest to naturalists, perhaps, is the reaction to salt solutions, as it has long been a question to what extent sea birds drink sea water or tolerate it in their food. My gulls were fresh-water birds, of course, as they came from Green Bay, but field observations on salt-water gulls are in agreement with my experimental results, so far as they go.

My own observations indicate that herring gulls, in cold weather, at least, do not need to drink often. They do not wander far from land relatively, and they are probably usually within a reasonable distance from fresh water.

Though fish and other meat that has begun to spoil are eaten to some extent by very hungry gulls, fresh food is evidently preferred. My captive gulls never touched spoiled liver, for instance, if not very hungry, though fresh liver was taken promptly at such a time. Liver which was just beginning to spoil, if eaten, was not taken with the same greediness, and a smaller quantity was swallowed. The first piece of tainted meat might be taken eagerly and sometimes partly swallowed, only to be rejected. One or more pieces might be swallowed in haste if the birds were exceedingly hungry, before signs of disgust appeared. Other pieces were handled with care on the same occasion, if touched at all. Bread which had been soaked in water that had contained such food as fresh raw liver was eaten more eagerly than when plain water was used to moisten the bread.

It was a common practice of my captive gulls to carry some of their food to their swimming tank, where they would play with it in the water. A piece of liver would be held in the beak and moved about under water with quick jerks of the head or dropped in the water to be seized before it had sunk far. This performance happened more frequently when the food had been lying in a chemical solution or when it had accumulated considerable dirt as a consequence of having been dragged on the ground. Such rinsing of the food did not occur at every feeding, but was usual. The extent to which the food was thus treated also depended upon the degree of hunger. When very hungry, food was bolted in a few seconds without much playing with it except sometimes with the last piece taken if hunger had been satisfied by the amount of food placed before the birds.

4. *Other reactions.*—It is generally known that birds have a special development of nerves and endings of general sensation about the mouth with large trigeminal nerves for the sense organs involved. It is consequently reasonable to expect that my gulls when suspiciously manipulating food of uncertain palatableness employ their general sensation to a large extent. We do not know to how great an extent general sensation and the taste sense are used relatively by birds, but such information as is available indicates that the former plays the larger part. It has been shown by Botezat[1] for the birds which he studied that taste endings occur only in the back part of the mouth cavity and especially at the entrance to the gullet. In some birds they were also found at the base of the tongue, but they were never numerous.

On the preceding page I describe the behavior of one of my gulls when it started to eat liver which had been lying in solutions of table salt for a few moments. The piece of liver was manipulated in the front part of the mouth at the tip of the beak by the apparently suspicious bird. No avoiding reactions resulted and the food was often swallowed. Such a result suggests that the region of the

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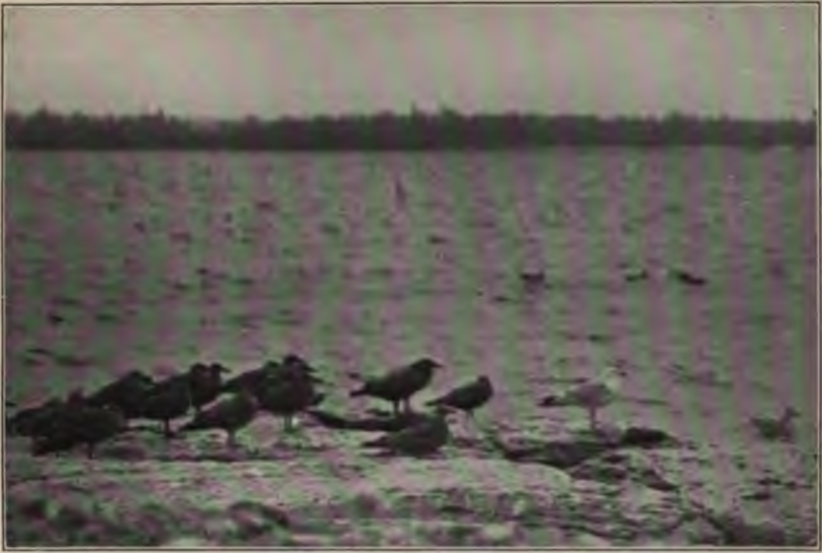
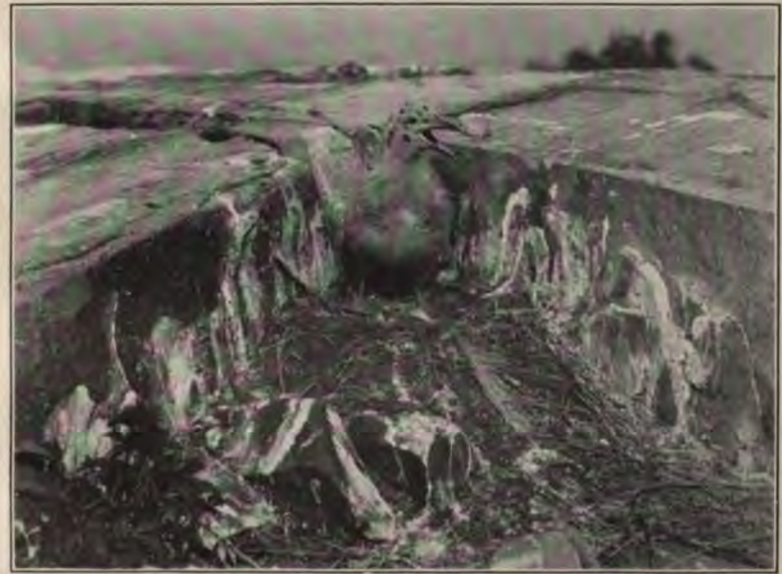
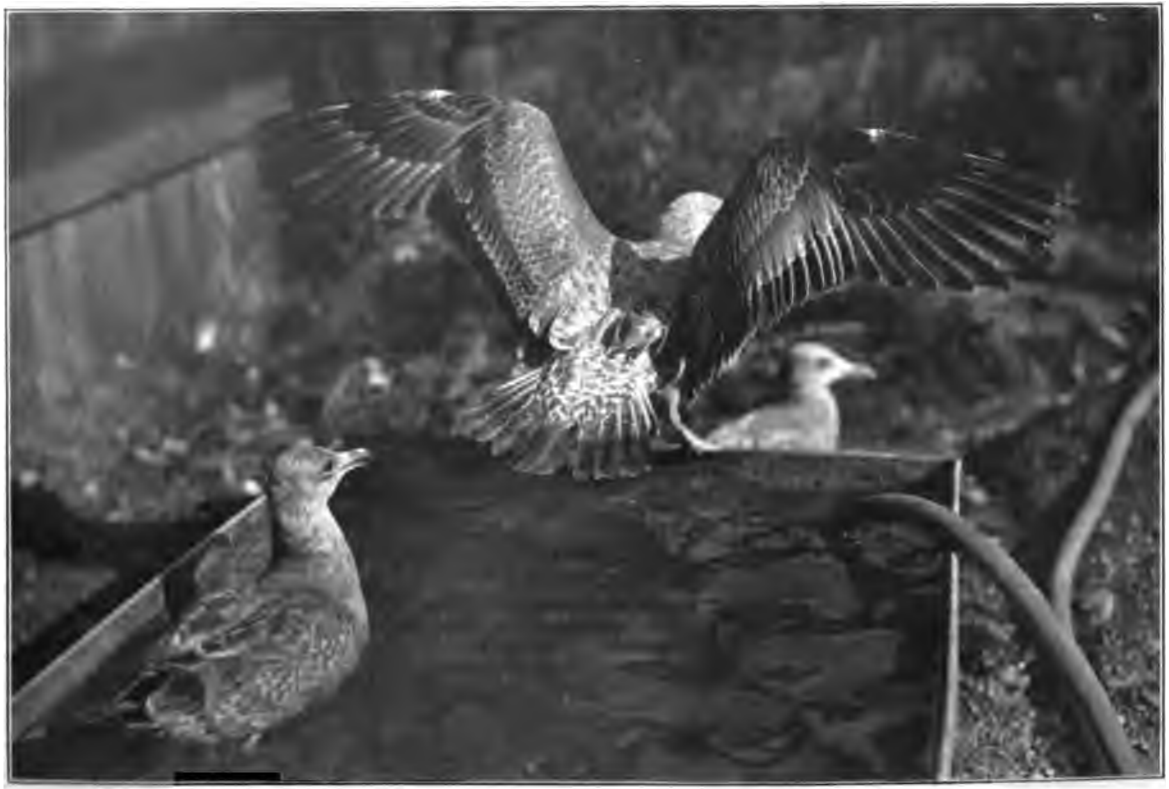
[1] Botezat, E., Die Nervenendapparate in den Mundteilen der Vögel und die einheitliche Endigungsweise der peripheren Nerven bei den Wirbeltieren: Zeitschr. f. wiss. Zool. Bd. 84, 1906, s. 205-360.



1. GULLS FACING THE WIND IN A STORM.



2. YOUNG GULL, HALF GROWN BUT STILL IN DOWN PLUMAGE.



HERRING GULLS IN JUVENAL PLUMAGE. ONE BIRD PERCHING AND ANOTHER SWIMMING.

mouth where trigeminal nerve endings occur is first used in testing food. It is quite probable that the salt solution adhering to the piece of liver did not stimulate the trigeminal nerve endings of the bird in the experiment and so was swallowed, with a consequent strong stimulation of taste endings as the food slipped into the gullet. I have made similar observations on this behavior of my gulls when given uncertain food, on a number of occasions. It is not improbable that mutual relations of stimuli exist between the general sensation of the mouth region and either smell or taste, or between all three. Readers who may be interested in the physiology of the beak region are referred to Edinger's[1] suggestions.

Gulls regularly show a positive reaction to strong air currents; that is, they face a heavy wind whether standing or swimming and usually when flying. This reaction is illustrated in plate 9, figure 1, where an adult and a number of juvenals are seen facing a heavy wind. Rain was falling when the picture was taken.

When the wind is exceptionally heavy, especially if rain is falling, gulls are commonly seen flying, and they face the wind a large part of the time. During an exceedingly violent storm which occurred in the early afternoon of July 15, 1911, when I was on one of the Sister Islands, all of the gulls able to fly took to the air. Their flight maneuvers were similar to those which gulls so often show over a beach during a gale at other times of the year. It is obviously more convenient to face a heavy wind, as the bird's body is adapted to meeting air currents head on with little horizontal resistance.

Extremes of temperature apparently give gulls considerable distress. On a hot day the brooding gull pants a great deal, even when perfectly quiet on the nest.

Young gulls, especially if excited, pant constantly when the temperature is as high as 90° F. (Pl. 9, fig. 2.) My captive gulls became very uncomfortable, apparently, and panted a great deal after taking only a few short flights of several yards each in their inclosure on a hot day. At such times they seek water and, if undisturbed, indulge in much bathing.

In zero weather (Fahrenheit) my captive gulls, though well fed and fat, appeared to suffer from cold, especially after eating cold food. When the ground was covered with snow or ice in zero weather, the gulls squatted upon their feet, apparently to keep them protected by their plumage. They rarely stood up at such times except when disturbed or to obtain food. They also showed their sensitiveness to cold by shivering, although probably in perfect health. Wild gulls with abundant opportunities for flying apparently keep warm by being active, and I have not seen them showing such distress from cold.

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[1] Edinger, L., The relations of comparative anatomy to comparative psychology: Jour. Comp. Neur. and Psych., vol. 18, 1908, No. 5, pp. 437–457.

Also see Vorlesungen über den Bau der nervösen Zentralorgane des Menschen und der Tiere. Bd. 2. Aufl. 7, 1908 (or a still later edition). Leipzig, F. C. W. Vogel.

IX. BATHING AND DRINKING.

References have already been made in this paper to the frequency with which herring gulls bathe in warm weather. My captive gulls enjoyed swimming and bathing in their tank, even in winter, so long as the temperature of the air was not very much below freezing. When swimming, the herring gull sits high on the water, probably in part because of the large amount of air contained in the dense ventral plumage. Possibly this extreme buoyancy, which also involves a large pneumatization of the skeleton, explains the fact that gulls do not often dive to the extent of completely immersing their bodies.

When bathing the herring gull dips its bill, and often the entire head, into the water with rapid bowing movements. At the same time the wings are flapped vigorously and water is splashed over the entire body. The performance is more or less the same whether the bird is floating on water or standing in shallow water.

During the colder weather of the winter my captive gulls were deprived of all opportunities for bathing, as their tank was emptied. They became very dirty, consequently, in a city like Chicago. With the coming of each spring the tank was refilled and a regular orgy of bathing followed. Each bath lasted for several minutes and was followed by feather dressing and partial drying of the plumage. Then another bath was taken. This would continue for an hour or more. In the course of two or three days the plumage became quite clean.

On July 29, 1911, I found a young herring gull at one of the Strawberry Islands in well-developed plumage and apparently old enough to fly. It was sitting quietly on the ground at the base of a tree 50 feet from water. On examination I found the bird to be very much emaciated; it was too weak to make effective efforts to escape—in fact it could not stand upright. I took the gull to the water and gave it a chance to drink. It was evidently very thirsty and drank eagerly. After taking what water it wished the bird took a bath, going through such movements as its limited strength and my grasp would allow. During the following week I gave this bird frequent opportunities to bathe, always holding it in my hands, and the bath was always taken without hesitation. The principal features were a plunging of the head under water with a quick removal, followed by a shake of the head, which splashed water over the body. This bird ate ravenously, but it was too weak to stand up for any length of time and died in about two weeks. An autopsy was performed by a pathologist, who was unable to find any other explanation for its death than the starvation the bird had experienced before I found it.

During the bathing performance the gull appears to drink more or less water, but it is difficult to say how much is taken. In hot weather there appears to be considerable water drinking by brooding birds. The gull which appears in plate 5, figure 2, was studied carefully from my tent for several hours on June 26, which was a very warm day. During the middle of the day this bird made trips to the beach edge for water so frequently that I timed some of the periods. I found that the intervals between drinks varied from 3 to 10 minutes. There was more or less bathing each time the bird went to water. I did not note any water drinking by gulls not brooding at the breeding place.

My captive gulls seemed to need very little water to drink in cold weather. During the first winter it was my practice to take warm water to the gull yard, which would not freeze over immediately. In the winter of 1911–12 the temperature was below 0° F. for some weeks, and during quite a portion of this time there was neither snow nor ice in the place occupied by the gulls. No other opportunities were present for the gulls to secure water than in their food or in the very slight amount of water which adhered to the food, mostly liver. I never saw any evidence of interest in the water which I brought to the gulls and they seemed to thrive without it.

X. PERCHING.

The herring gull, being a web-footed bird, would not be expected to have a perching habit, nevertheless it does perch sometimes, after a fashion. One of my captive gulls may be seen in plate 10 perched on the side of the swimming tank, a position not infrequently assumed by these birds on leaving the water. On July 29 I saw herring gulls perched in the foliage of the upper outermost branches of tall trees on one of the Strawberry Islands. They did not remain there long and they presented the appearance of standing on foliage rather than on single limbs.

Other observers have reported seeing herring gulls perched in trees. Of course there is no such gripping of the perch by the feet of a gull as is done by a true perching bird.

XI. COMPARISON OF DIURNAL AND NOCTURNAL BEHAVIOR.

As Herrick[1] has well said, there is no repose by day or night in a gull colony. Adults take naps at all hours, either while on the nest or standing near. Often they simply doze, with the head drawn close to the body and the eyes shut, or the bill may be tucked inside a wing with the eyes either open or closed in view. During the day groups of gulls stand about dozing, as may be seen in plate 8, figure 2.

In order to get an idea of the entire daily cycle of activities at a gull-breeding place, I spent a night at one of the Strawberry Islands.

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[1] Herrick, F. H., The home life of wild birds. Revised ed., 1905, p. 112. Putnam's Sons, New York and London.

I arranged my trip so that it would cover those hours not included on other days. Ward also spent a night at a gull colony, and I quote his interesting account [1] of his experiences as follows:

> Sleep seemed to occur perhaps a little more frequently during the warmer hours of the afternoon than at other times, though pretty evenly distributed through the 24 hours. The birds sometimes stood, but more frequently squatted on the ground and turned their heads over their backs and tucked them under their wing feathers. Sleep was of very short duration, as fights, panics, and alarms of various sorts followed one another too closely to allow of unbroken repose for more than a few minutes at a time. The night that I spent among them there was less sleep than during the day. The sun set about half past 7, but at 8 o'clock the colony was as busy as ever fighting, making abortive nests, and screaming. At 10 minutes past 8 the moon arose, and 10 minutes later nearly all the gulls suddenly took wing in what I conceived to be a panic, until shortly afterwards I spied a large flock of them on the water in the direction of the moon. Later they worked around the island, so that I was between them and the moon, and I could then see that they were busily fishing. My notes continue up to a quarter of 3, when I fell asleep with the gulls still on the water and noisy. When I awoke at 20 minutes after 4 the sun was up, most of the gulls were on the island, and many young were teasing a few adults for breakfast.

On July 7, 1911, at 7.20 in the evening, I was on the island and I left the next morning at 7.05. My blind was erected and I was inside ready for work at 7.45 when my companion left the tent and went away in the motor boat that had brought us. Within 10 minutes the gulls had settled down to normal activities, i. e., when the boat had gone a fair distance from shore. The "challenge" and mewing cries were made a number of times during the following half hour. I also heard the quack of a red-breasted merganser occasionally during this period, and a bronzed grackle flew near the tent. At 8.25 a spotted sandpiper call was heard, also a very young gull apparently calling for food. By 8.40 it was too dark to see my writing and the gulls were quieter. There was an outbreak of noise, however, at 8.43, which lasted for a minute or so. I used a small pocket electric flashlight, carefully concealed during the night, to see my watch and to make notes.

About 9.30, when the sunset glow was practically gone, a board was knocked down from one end of my tent, making a noise which alarmed the whole colony, and no birds came near my tent except in flight, so far as I could determine, until daybreak. The moon set about 1 a. m., and there was only starlight. I could not see any birds, but I could hear them flying about all night, giving the alarm cry at intervals. The gulls were less noisy from 1 to 2.45. Small juvenals were heard calling occasionally through the night.

Shortly before 3 the first glow of approaching day appeared in the east, and the gulls began to settle down near my tent. They also became very noisy, especially with the challenge cry. At this time

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[1] Ward, H. L., Notes of the herring gull and the Caspian tern. Bull. Wisconsin Nat. Hist. Soc., vol. 4, No. 4, October, 1906, p. 132.

I noted a female red-breasted merganser playing in the water not many feet away. Song sparrows were singing, and bronzed grackles were active. A few minutes later a very small juvenal gull ran to the edge of my tent some 50 feet from where I first saw it. It passed within 5 feet of two adults, who gave it no attention. The sun rose about 4.20, and at 4.25 two adult gulls came within 3 feet of my tent, where they remained about a minute. They then flew away a short distance and returned to a point about 10 feet distant. No birds were seen on nests, as the incubation season was over on this island.

At 4.40 I noted gulls bathing, and at 5 I saw a very small juvenal paddling ashore. A fight occurred between two adults which was broken up by the interference of a third adult. About the same time I saw an attack on a juvenal gull by an adult resented by another adult. Challenge cries and mewing calls made a great noise at this time. Other juvenals which had been standing near the place where the attack was made disappeared.

A few moments later I saw three gulls worrying a great blue heron in full flight, much as kingbirds harass a crow. The heron finally disappeared in the woods on the largest of the Strawberry Islands, where a heronry was located, and from which I had heard noises throughout the night.

Another fight between adults occurred at 5.15, and, as usual, with no apparent injury to the participants. When the contest was over the two birds faced each other and made a feint at renewing hostilities. Then they went through the challenge performance simultaneously.

At 5.25 I noted that I had seen no feeding and that most of the juvenals gave no evidence of desiring their parents, but at 5.45 I saw a downy juvenal teasing an adult for food, and a feeding occurred a few minutes later. After the feeding both birds drank water, and the adult swam out from shore about 20 feet where it took a bath. I noted at 6.25 that downy juvenals were standing idly most of the time or dressing their plumage. An adult approached a juvenal, and another adult flew to the spot, apparently to drive the first adult away.

I was unable to determine what the gulls were doing during the darker part of the night after the setting of the moon beyond the flying already mentioned. Judging from the sounds, many of them were on the water, as was the case during Ward's night at Gravel Island. Whether the falling of the board had anything to do with the absence of the gulls from at least my part of the island is uncertain. As the birds left Gravel Island at nearly the same time in the evening according to Ward's observations, there is some reason to believe that the board accident was not responsible. It is conceivable that there was some fear of the tent in the darkness which did not exist in daylight. Or possibly the birds feel safer on the water at night and are in the habit of remaining there in a flock during a major portion of the night when uneasy.

During the night of July 5 and 6, 1907, I camped on Partridge Island, in Lake Superior, about 1 mile from Gull Island, where a colony of gulls were breeding. In the latter part of the night, just before dawn, I heard the cries of gulls flying overhead. The night had been very dark as the sky was clouded.

Some observations on the nocturnal activities of herring gulls have been reported by Schuster.[1] He noted these birds feeding on the river Mersey at Liverpool. Large quantities of food, thrown into the river at night from ships, are stated to be responsible for this nocturnal feeding. The gulls are described as flying and feeding silently.

Various writers speak of gulls "roosting" at night, and my captive gulls apparently sleep during the night, as a rule. It seems probable that gulls usually rest during the night, except during the breeding season or when food is especially available at night. It is also probable that gulls are not active when the darkness is intense.

XII. VARIABILITY AND MODIFIABILITY IN BEHAVIOR.

According to Herrick,[2] whose conclusions are in general supported by my own observations:

> The life of birds is one of instinct irradiated by gleams of intelligence. Their mental faculties exhibit a wide range of gradation from excessive stupidity to a fair degree of intelligence with strong associative powers of things with ideas.

In my study of the herring gull I have been especially interested in attempts at determining the extent of the "gleams," a fascinating but very elusive topic. The resourcefulness which animals show in new situations and the extent to which their behavior may be modified by new conditions may be considered fair criteria of their intelligence. Variability in behavior, however, has some bearing on the problem of intelligence. We must recognize perhaps two types of variability in behavior which do not indicate intelligence as it is commonly understood. They may even tend toward confusion in our analyses of behavior, as acts which may seem to indicate resourcefulness or adaptiveness may be only variations in stereotyped behavior.

It is to be expected that so-called pure lines or strains may be found among the behavior characteristics of a species as well as in other characters. Some of these strains may possibly be the result of or be accentuated by such segregation as is afforded by separate breeding places. Unfortunately we know nothing concerning the relationships of individuals in one colony to those of another. We have no information concerning whether gulls breeding at one of the Strawberry Islands, for instance, have interbred in recent years with Gravel Island gulls. Furthermore, we have no data, as yet, concerning the existence of definable pure lines in the morphological characters of herring gulls.

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[1] Schuster, W., Möwen als Nachtvögel. Zool. Beob. Frankfurt a. M. Jahrg. 47, No. 3, S. 79, 1906.

[2] The home life of wild birds. Revised ed., 1905, p. 212. G. P. Putnam's Sons.

The other type of variability in behavior is not associated with pure line inheritance. It represents simple chance variations from the average type of behavior which are to be expected just as we find variations in morphological characters.

In the section of this paper which deals with the general behavior of juvenal gulls I mentioned variability in the behavior of some newly hatched gulls. A single bird in one nest showed no terror, whereas two nestlings of essentially the same age in another nest were in great distress from fright over the presence of human intruders. I can think of no reason for considering that either the quiet bird or the frantic pair were more intelligent or that either form of behavior was adaptive. Nor have we reason to believe that it was a case of pure line differentiation. It seems quite possible that chance variations in the metabolic states of the birds or possibly in their nervous organization were responsible for the difference in reaction to our presence. It is conceivable that the reactions would have been either similar or reversed if we had approached the nests a few hours later.

A large amount of variation has been noted in the choice of materials used in constructing the nest. Evidently the herring gull uses what is available with a preference for finer and softer materials. It seems probable to me that such nest building, which is evidently mostly instinctive or stereotyped, is not absolutely without the elements of intelligence. There must be adaptation of special materials which may be found, to use and location. Though the general form, size, and location of the nest are characters of the species, the variations which fit the nest to its special location, for instance, are no more stereotyped than various acts of man which are called intelligent.

As a consequence of persistent nest robbing, gulls at certain breeding places have been reported as taking on a tree-nesting habit. I know of no evidence worth considering for believing that the recent ancestors of such birds were tree nesters, and we have every reason for considering the inherited choice of location for most herring gulls as on the ground.

We have already seen in this paper that even the structure of the nest may be modified in adaptation to the location in a tree. More skill is shown in weaving the nest, according to reports, so that it will hold together in its tree location. Of course it may be said that tree nesting by the herring gull may be due to a so-called latent instinct which appears when persecution compels the bird to seek a safer place for its nests. We have, however, no reason to believe that instinct behaves in inheritance differently than other characters. Our knowledge of the laws of inheritance does not furnish any basis for thinking that an instinct for tree nesting can exist for long periods of time in a species that has another habit, without itself appearing.

Herrick[1] seems to consider tree nesting for the herring gull to be a variation without much significance. He found a small percentage of gulls nesting in trees at a height of from 6 to 10 feet. In his judgment, this position affords no protection to the birds. I have seen no nests above the ground, though trees and bushes cover most of the ground on all but two of the islands where I have seen gulls breeding.

To me such tree nesting as Audubon[2] described suggests real resourcefulness, but we know too little about it to be warranted in making any generalizations concerning the intelligence it may involve. In some colonies tree nesting may possibly be the inherited habit or instinct of certain strains or "pure lines" of herring gulls.

The nestling offspring of tree-nesting gulls are reported as remaining in the nest when observed, though gulls of the same age on the ground would never be found in the nest, but would always be hiding. That tree-nesting juvenals do not leave their nest until they are able to do so without injury is probably due to a realization of the danger involved in such an attempt. This remaining in the nest under such circumstances may possibly be regarded as intelligent behavior of perhaps a low order which prevails over any blind instinct to leave the nest to hide when intruders appear. Just how much this behavior is tied up with instinctive activity is of course beyond our knowledge.

The promiscuous feeding of juvenal gulls at Gravel Island appeared to me to be a variation from the probably usual habit of parents feeding their own offspring. Unfortunately, we lack data for establishing the extent of this variation. It could easily be the consequence of the congested life on the island. I have noticed that juvenal Wilson's terns seek food of any adult that may happen to come near them with food in its beak, but all of my observations indicate that the parent tern probably feeds its own offspring. The gull must go through the somewhat complicated process of regurgitation, which seems far from voluntary. Large numbers of juvenal gulls crowding about an adult who, perhaps, sees its own offspring in the mob may be able to snatch the food regurgitated without regard to parental relationships.

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[1] Herrick, F. H., Nests and nest building in birds. Part 2, Journ. Animal Behavior. July-August, 1911. Vol. 1, No. 4, pp. 244-277.

[2] Audubon, J. J., Ornithological biography. Edinburgh, 1835., vol. 3, pp. 583-589.

A large number of so-called lower birds like ducks, coots, etc., and the various species of gulls learn rather rapidly where they may feed and breed without molestation by man. In the course of only a week wild ducks become far less shy on bodies of water in or about cities than when they arrive, a matter of common observation. Gulls likewise recognize even more positively that they are relatively safe in such places, but they are exceedingly wary wherever shooting occurs. Such discrimination undoubtedly involves at least the rudiments of intelligence even though the activities in question may be largely instinctive.

I had hoped to carry on some experiments on modifiability in behavior with gulls, but my time was taken up so largely with the general observations which I thought should come first that only a single experiment was started. An entire nest was moved 4 feet to one side at a distance of about 100 feet from my tent. The nest was under observation for several hours, and what appeared to be the owners were seen standing about the spot where the nest had been located. Though the birds seemed to be disturbed, they did not make any significant demonstrations of excitement, and they did not attempt to brood the eggs.

SUMMARY.[1]

1. The herring gull is gregarious in habit, but it is also quarrelsome. Some of the fights are undoubtedly the consequence of invasions upon nesting precincts, as stated by Herrick, but many are probably due to simple belligerency. This bird is often a great coward and may be routed by smaller birds. The fights between adults have always been harmless, in my experience. Herring gulls will fight fiercely for food when very hungry.

2. Herrick's conclusion that the frequent killing of the young by adults is the consequence of the instinct to guard a nesting precinct probably holds true in many cases. There is, however, some evidence that this is not always the explanation. Juvenals sometimes attack younger birds just as savagly as the adults do and in the same manner.

3. Other birds often nest safely even on a small island densely populated by breeding gulls.

4. The herring gull nests usually in places the most inaccessible to man that are available. The breeding place is usually on an island not inhabited by man. When seeking food or aside from the breed-

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[1] This section is not complete. It includes principally the more important conclusions of this paper.

ing season this bird is frequently to be seen near human habitations on the coast or following vessels.

5. This gull is practically omnivorous in its habits, according to the observations of various writers. Animal food is preferred, but other food may be eaten if the bird is hungry enough.

6. The herring gull does not dive for its food to any extent, and it never plunges vertically into the water, as terns do.

7. The nests are made of such material as is available, but fine materials are preferred.

8. The offspring are shaded by their parents on a hot day until they are strong enough to leave their nest and seek a shaded spot.

9. The young are given food which is first regurgitated upon the ground. There may be promiscuous feeding of young birds by adults not their parents.

10. Herring gulls which I have had in my possession since they were in the nestling-down plumage were less mature in plumage at two years than is indicated by Dwight for birds of that age. It is my judgment that herring gulls rarely breed before they are 3 years old. All of the breeding herring gulls which I have seen were adults, so far as I could determine.

11. It has been my experience that the young are at least 2 months old before they begin to fly well.

12. I have given especial attention to the voice of the herring gull. The most frequent sounds are the "challenge" and the "alarm" cry. A "mewing" sound is fairly common. These cries all involve characteristic positions, especially the "challenge" and "mew." The "challenge" seems to represent a variety of emotional states, but, in general, excitement. The young have a characteristic squeal or chatter, which is high pitched. It is used in calling for food or with a little modification when frightened. My captive gulls began to use what appeared to be a rudimentary "challenge" cry in September of their first year.

13. Both vision and hearing are keen in the herring gull, as appears to be the case with most birds.

14. It has been my experience that the herring gull has nearly as good darkness vision as man at least. During the breeding season, or when food is best obtained at night, this bird is active at night. My captive gulls would eat, if very hungry, when there was barely light enough for me to distinguish their food.

15. Food which is wet with solutions of either table salt or acids is rejected. My birds detected the presence of these solutions even when they were very weak to my taste.

16. Meat is eaten much more readily when it is fresh. The extent to which spoiled meat is tolerated varies directly with the degree of hunger.

17. It is a common practice of these birds to rinse in water food of uncertain palatableness or when it is dirty.

18. Some evidence was obtained concerning the use of nerves of general sensation in testing food.

19. A positive reaction is shown to air currents. In a severe storm gulls leave the ground and indulge in flight maneuvers.

20. The herring gull is sensitive to extremes in temperature. In very cold weather the feet are kept protected by the plumage a large portion of the time.

21. There is a large amount of bathing, especially in hot weather. In very cold weather no water seems to be required beyond that present in the food obtained.

NOTES ON SOME EFFECTS OF EXTREME DROUGHT IN WATERBERG, SOUTH AFRICA.[1]

By Advocate EUGÈNE N. MARAIS, R. J. P., Rietfontein, Waterberg.

The gradual but continuous diminution of the surface water of the earth is undoubtedly the chief element in our cosmic history since long before the advent of man. The change in environment occasioned by it has been the great moving cause of natural selection and the evolution of living species.

If we study this loss in the two continents where water has reached such a degree of scarcity as to render its present rate of lessening an outstanding natural feature, the progress not only becomes more noticeable, but also more easily measurable. In Asia and Africa, the two "dry" continents, the disappearance of water annually is so great that it seems to justify the prediction of the French astronomer, Flammarion, that within a measurable space of time the human race is to find in this cause its final eclipse. In Europe and America, the "wet" continents, water is still too plentiful to make its yearly lessening a matter of much moment; but they are certainly not exempt. If one compares, for instance, the facts disclosed in the histories of early Roman conquest with existing conditions, it would appear that what are now comparatively dry countries and fertile tracts were in those times an unending succession of marshes with broad sluggish rivers winding from mere to mere.

In Asia a comparison between the observations of the Russian explorers of 50 years ago with those of Sven Hedin reveals the fact that even in that short space of time the desert has taken in thousands upon thousands of square miles of once fertile country. Rivers and lakes have vanished and even populous cities have been obliterated by the all-conquering sand.

Just as rapidly are the great lakes of Africa shrinking. Our own N'gami was a real lake less than 50 years ago; now it is no more than a marsh threatened with speedy extinction. Lake Rudolf, that most perfect diadem in the girdle of the globe, is approached on one side (that opposite Rowenzori) over enormous plateaus of dry mud which were quite recently covered by the waters of the lake, and yearly a new belt is added to these mud flats, a process that becomes alarming when one remembers that upon this great natural reservoir largely depends the fate of the Nile and of fertile Egypt.

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[1] Reprinted by permission from the Agricultural Journal of the Union of South Africa, February, 1914.

Nothing is more fallacious than the old doctrine that evaporation and precipitation of moisture constitute a perfect cycle without the possibility of loss. As a matter of fact the earth is sucking up moisture like a sponge, and a vast quantity each day penetrates the surface to subterranean depths from which no natural cause releases it again and where it is apparently beyond the reach of man's utmost ingenuity.

The recent geological history of Waterberg in this respect is extremely interesting and convincing. That in quite recent geological times the major portion of its surface was covered by a great lake is a thing beyond question. The barrier of waters to the north was a plateau of which a portion still remains in situ. A few of the original islands, now strangely formed lamboidal hills, with wave marks still visible on their rocks, stand like a row of sentinels in the low country just beyond the edge of the plateau. From the south great rivers deposited their shingle on the shores and bottom of the lake. Some upheaval destroyed all the eastern portion of this barrier, and the confined waters escaped northward and eastward to form new rivers when the first floods had subsided. The shingle mixed with the lake sand was buried under the products of this eruption, and after being subjected to immense pressure, the lapidescent stuff was by another cataclysm released and scattered over the entire district, where it is now known as Waterberg conglomerate. On the highest hills and in the lowest valleys you find it studded with highly polished lacustrine pebbles, as if yesterday they had been taken from the water. Only on uninjured fragments of the plateau which once formed the heights above the lake shore you find none of it, but on the slopes of this high country, just below the surface, one finds layers of beautiful lacustrine shells sometimes 2 or 3 feet in depth.[1] Since that debacle the geological history of Waterberg has chiefly been one of rapid desiccation. Broad over its surface lies the writing which he who runs may read. There was a time within the memory of white men, when every kloof and donga was the bed of a perennial stream of crystal water and the district generally was so marshy and "vals" as often to render a passage by ox wagon a hazardous undertaking. In those times was its present name bestowed on the district—a name that to-day seems to have originated in the bitter irony of some disappointed voortrekker.

Even within the last half-century Waterberg was, to dwellers on the high veld, synonymous with a sort of lotus land of fertility, literally overflowing with milk and honey. So plentiful were these two emblems and proofs of fruitfulness that the good wives of those times fattened their pigs on a mixture of expressed honey and "thick" milk. Fruit, wild and domestic, was proverbial for size and plenty.

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[1] On the farm Rietfontein No. 1944 a layer of these beautiful shells, of all shapes, were found at 26 feet.

Every farmhouse had a water mill, and a spirit-still smoking night and day. It was the last great stronghold of big game in the northern Transvaal. It will be remembered that it was to Schimmel-perd-sepan that Markapan invited Commandant Potgieter for elephant shooting when he had planned the murder. It is perhaps true that man had here also to procure his bread in the sweat of his brow. He had to work in order to live, but his work was so uncommonly like play that not without reason was the district named "Lui-lekkerland." A salted horse and a good rifle were the prime necessaries of life, and many a fine farm was swapped for one of these.

That was the picture then. And now? *Tantaene animis celestibus irae?*

Last season was a culmination of several drought years. It was the worst drought ever experienced in this district since its settlement by whites, and this statement is made on surer evidence than the unassisted recollection of the "oldest" inhabitant. One can not be too doubtful of such evidence. By an eclectic acceptance of such statements one can find foundation for almost any sort of theory. Even one's own recollection must be consulted with considerable reserve. No one who has grown up in this country but seems to remember a Transvaal of broad deep rivers, of mighty rains, of beautiful springs, spruits, and waterfalls. Valuing this no more than one would hearsay evidence in law, there is in Waterberg a mass of confirmatory evidence which places the above statement beyond doubt. Take only one fact: Last season a large number of orange groves perished from drought of which the trees were over 50 years old. And in addition to the facts such as these, a little study of drought conditions and the diminution of existing waters soon enables one to follow the ancient spoor of once living streams, and even to assign an approximate date of their final disappearance. With such collateral evidence human memory can, *tant mieux*, be valued correctly. The assertion, therefore, may be safely accepted that last year was the worst drought year experienced in this district since the advent of the voortrekkers. Over the greater portion of the district the first rains did not fall before the middle of November, and over about half of the northern middle veld no rain fell at all, that is to say not sufficient rain to cause the veld seeds to germinate and the plants to grow. This season has, in certain respects, been even more disastrous. In the early part of the season there were good but purely local showers. The grass and shrubs in these favored localities started fairly well, and then when rain was most needed for crops and veld alike it ceased altogether. This refers to the plateaus and mountains. In the north, with the exception of one or two localities, no rain has fallen this year, and again it is the end of November.

The effects of such a drought open a vast field for research, of which almost every ascertained fact would be of the most vital importance to the inhabitants of South Africa. Not to the naturalist only are these facts of interest and value. To the farmer their study would afford an essential arm in his struggle for existence. In an article such as this it is possible to touch on a few of these facts only. Many experiments and comparative measurements were made which might be of some value for the purposes of exact research, but a detail of them would hardly be admissible here. I will confine myself therefore to a brief description of the more immediately perceptible effects of the drought on surface water, on plants, and on animals—facts that would strike any observant visitor.

It is impossible, unless one saw, to conceive the scene of utter desolation—that once famous hunting ground between Gaul and Magalakwen, extending northward from the mountains, to the Limpopo and constituting the lateral watersheds between the three river systems. The two rivers, Magalakwen ("the strength" or "stronghold of the crocodile") and Palala ("the hinderness," "the stoppage," "the impossible"), bearing in their native names proof of their former greatness, are to-day mere ribbands of sand winding through desolate sand dunes to the Limpopo. For some distance along their course one can still secure water by digging holes in the sand. It will try the reader's faith to learn that in the entire district of Waterberg there is at the date of writing with perhaps one exception, no running river or spruit, and Waterberg is, I believe, considerably larger than the Free State. In the north of the district there is a tract over 4,000 square miles in extent in which there is no single drop of water running or stagnant above the surface of the ground.

Schimmel-perd-se-pan, the last great center of elephant hunting in the Transvaal, received its name from the legendary feat of an intrepid voortrekker, who, braving its dangerous subaqueous weeds, swam his horse across the pan with a quarter of an eland behind the saddle. Now there is never more water in the pan than can be covered with a lady's pocket handkerchief. The water supply consists of a tiny pool deep under a sheltering rock, and at the time of writing this has shrunk away till nothing is left but a patch of damp sand. Similarly have all the famous old waters of the great hunting days disappeared for the first time within the memory of man, although to those who had an opportunity of studying their annual shrinkage their fate has for many years been a foregone conclusion. Tambootie, a huge marsh, always dangerous to cross; Sandmansfontein, a beautiful strong spring in the hills, named after the only hunter who attempted to make his home there in the old days; Bobbejans Krans, where the water boiled out under a precipice and where the finest Kaffir cattle in the middle veld were to be seen, three years ago—all have vanished, and with the ending of the waters the great herds of cattle have fled in all directions. All that once teeming pasturage lies dead and desolate.

But it is not in the middle veld alone that this state of affairs obtains. There are hundreds of farms in our immediate vicinity which have the same tale to tell. One can take them absolutely at random. Zwartkloof, for instance, was selected by the late Mr. Piet du Toit, a voortrekker, on account of its magnificent water supply. Up to recently it was still renowned as one of the best wheat farms in our ward, and its great herds of wild red Africander cattle were hunted and shot like big game up to the time of the rinderpest. The present joint owners, Messrs. Franz and Nols du Toit, were born on the farm. The former is now 65 years of age. He declares that never in his lifetime was there even a perceptible lessening of the spruit. To-day a well, 40 feet deep, sunk in the source itself, is as dry as a bone. There is not a drop of drinking water on the farm. Thirty years ago there were no less than 11 perennial springs in its veld. And this same story can be told of almost every occupied farm in Waterberg.

The great Limpopo itself is dry for all the distance that its course delimits this district. Only by deep digging in its sandy bed can drinking water be found. The larger seacow pools, it is true, still contain stagnant water, but the majority of these are almost putrid. The smell of fish and crocodile poisons the air in their vicinity, and it would be courting death to drink the soupy liquid they contain without previous filtering and boiling. After the recent heavy rains in Pretoria and Rustenburg, and the floods consequent on them, the running water in the Limpopo reached 30 miles above Silika's Stad and was there—a mere futile trickle—lost in the burning sand of the river bed. Of all the immense quantities of water which at that time drained off the northern slopes of the high veld, and at one time most of the tributaries of the Limpopo were flooded, not one drop reached the sea in the shape of flowing water.

The only waters in the district which remain unaffected by the drought are the fairly numerous thermal springs. The farm on which the writer resides is dependent for all its water, both for drinking and irrigation, on a thermal spring, and careful measurements during the past five years show no diminution at its source. But this year the loss of water between the source and the dam inlet is 60 per cent more than it was three years ago on the same date.

The effect of the drought on plants was naturally in exact proportion to its effect on surface waters. Early in the season of 1913 the belief gathered strength that a large proportion of sweet grass clumps in the affected veld were quite dead. The deepest roots under magnification showed a state of desiccation precluding the possibility of life. This, however, was strenuously combated by the experience of old settlers. They seemed to think that no amount of drying-out could kill grass clumps as long as they remained in the ground. To decide the question it was attempted to start growth in 200 clumps of sweet grass of different varieties growing on zoet-doorn-veld by damping and shading. The result proved that 92 per cent were quite dead. The average number of seeds that germinated in and near these clumps was three. Before the end of the season, however, most of the seeds represented by this artificially induced growth were in turn destroyed. Just enough rain fell to start germination, and when they were at the tenderest stage of growth the sun scorched them to death. The result is that an enormous extent of sweet veld has been destroyed. On this farm the sweet veld looks more like a barren "brak" than the luxuriant pasturage it once was.

The coarser "sour" grasses (Aristidas) to a great extent escaped complete destruction. By their habit of growth the clumps are better able to resist drought. The thick fibrous covering just above the ground affords more root shade and is a better absorbing medium than the scantier clumps of the finer grasses. It seems to me quite evident that these so-called "sour" grasses are comparatively recent invaders from the desert north, where natural selection had long since fitted them to resist similar conditions. The native sweet grasses not able to adapt themselves to this changed environment are losers in the struggle for existence. Therefore is it that all our sweet veld is yearly diminishing and the sour veld extending. In fact, it is almost impossible to get quite pure sweet veld in Waterberg. Our best sweet veld would have been called "mixed veld" a few years ago. In the olden days Waterberg was a sweet-veld district.

It is in their seeds that one can best see the high specialization attained by the sour grasses as drought resistance. Their manner of distribution and habit of growth were all evolved under stress of waterlessness in some semidesert country. Their life history is one of those fairy tales of botany that might be of interest even to the busy man who has no time to notice. With a body shaped like a torpedo and a long tapering tail, they have attained in perfection the tadpole shape, which nature finds of such advantage that she has evolved it a thousandfold in the highest and lowest forms of life—indeed it is probable that from such a shape have all organic forms originated. Under low magnification it will be seen that both body and tail are thickly studded with sharp stiff bristles growing backward. The point of the torpedo is an intensely hard horny spike, sharp as the point of a needle with a coronal of harpoon points at its base. The seed is thus able to cling to the coats of animals, besides being easily moved off by the wind. But these qualities are of more immediate value in another direction. It is above all things a penetrating *machine*—how efficient one can judge from the fact that it is often found in the internal tissues of animals, having gone through coat, muscle, and flesh. It often penetrates human flesh, and is then always a source of serious danger. Every movement, however slight, causes the embedded seed to penetrate deeper, and frequently a serious surgical operation only can remove it. But it was not for this purpose only that its penetrative qualities were evolved. It is a common thing in good rain years to come across a mass of these seeds drifted together by the wind. It is then that one has an opportunity of seeing a wonder of plant life, quite startling in the apparent intelligence disclosed. The seeds as they lie are huddled and orderless like casually thrown spillikins. If one sprinkle a little water on the mass a tremor as of awakening life is almost immediately seen to pass through them. Movements in all directions follow; spasmodic jerks, twistings, and turnings, so animal-like as almost to leave one in doubt whether they veritably are seeds and not insects. And this doubt intensifies as the process continues and the purpose becomes more apparent. One sees that by these movements the seeds are disentangling themselves; and when this is effected, each one becomes engaged in independent movements. At first it all seems erratic and casual, and it is only after careful watching that it dawns upon one that all these movements are quite ordered and have a definite purpose. The first spring-like twistings lift the seedhead clear off the ground and free it from obstructing fellows. A bend of the tail, on which it then rests, turns the torpedo head point earthwards. It is gradually lowered until the needle point with its harpoon bristles is thrust into the damp soil with a steady and continuous pressure from the tail. This movement is continued until the entire seed is embedded, the whole operation occupying 15 minutes. But its chief protection against drought and the accompanying ineffective and, in fact, fatal night showers lies herein, that if the soil be only slightly damped the seed penetrates beyond the line of moisture and remains thus without germinating, ready planted, waiting for enough rain to insure the safety of the future seedling. This penetration is proportionate to the length of tail, and it will be found at the end of a season of severe drought that the species with the longest tailed seeds have started more seedlings than the relatively short-tailed. The hard shells of these seeds also require a definite and large amount of moisture to soften.

Of all these advantages the seeds of the sweeter and softer grasses are deprived. The clumps die and the seeds germinate with the first slight shower only to die next day in the scorching sun. And thus it happens that yearly the famous sweet veld of Waterberg is diminishing and getting more and more mixed and its value as a cattle district proportionately deteriorating. And not only are the sweet grasses thus handicapped by changed environment, but man enters into the fight against the losing species and by the annual veld-firing assists, and even completes, the work of natural selection.

And not the pygmies of the veld only have thus been struck down. The giants, secure in their strength and age, have not escaped. The big trees are leafless and sapless like a northern woodland in the midst of winter. On the higher "bults" 50 per cent of the springs and boekenhout are quite dead, food for the next veld fire. Among these dead trees there were many at least three centuries old—calculated from the annulation of timber sawn from them.

Even the most efficient waterstorers could not survive this terrific stretch of drought and heat. In the middle veld the little naevose aloe, common on our southern hills, grows plentifully on the flat, chiefly in the shade of thick bushes. Where this shade was in any way deficient they commenced dropping their leaves from the crowns downward, and before the middle of the season they were quite dead. Stapelias, those weird daughters of the desert, are here very plentiful. Under normal conditions they seem to shun every semblance of moisture by growing on barren shelves of rock, collecting a scanty soil by means of their own roots; even stapelias hang shrunken and flaccid on their rocks, and quite half the plants examined seemed quite dead.

It was a matter for surprise to find one of the best drought resisters in a larger hypoxis. Not only did it start a fair growth of fronds, but in shady places a few sickly flowers even appeared. This plant has a medium sized bulb, not nearly so large, compared with its growth above ground, as hundreds of others that perished. The bulb is enveloped in several layers of dry, perfectly waterproof husks, and is filled with a sticky orange-colored liquid. What made it of special interest was the fact that it was eagerly sought after and eaten by all kinds of animals in preference to any other plant procurable. Even the well-fed animals in our team were very keen after it.

On the animal world the effects were just as far-reaching and quite as noticeable. Those animals to whom escape was possible fled early from the stricken area—man among the first. The entire middle veld is without human inhabitant. Whites and blacks trekked north and south along the river ways with their stock as the waters receded, and a great many cattle have been sent on to the high country. For all practical purposes the north is a desert, and in many respects a worse desert than the Kalahari. In the middle of the day it is a scene of utter death and desolation. Not a bird sings, not an insect moves. Over everything seems to lie the silence of absolute lifelessness—a silence characterized by the true desert tinnitus. Elsewhere it is said that the wind bloweth where it listeth. Here—when there does come a breath of air—it has a strong predilection for one direction only; straight from the Kalahari, hot and scorching as the breath of an oven. It seems indeed as if the desert has reached out an arm and taken to itself for all time this great extent of once fertile country. For four and a half long hours each day in the coolest available spot the temperature never sank below the century.

This terrible heat and the absence of all moisture in the atmosphere has some singular effects on the human body and its immediate environment. The hair became so electrified that to stroke it lightly with the hand evoked a crackling shower of sparks. The finger-nails became so brittle that they were constantly breaking into the quick, and both the hair and nails seemed to have lost all power of growth. All celluloid substances were speedily broken up into thin laminae, and new rubber became in a few days a useless spongy mass. The horses' tails swishing their sides crackled incessantly and stood out in disheveled bushes, each hair apparently wired. When travelling at night their flanks were surrounded by minature auroras of electric discharges. To stroke the canvas with one's finger generated a discharge that could be felt in the hand. The big game had nearly all disappeared. The large herds of blue wildebeeste that frequented the rivers earlier in the year trekked down the Limpopo to the larger pools and across into Rhodesia.

The change of habit forced upon animals by this change in their environment was very interesting, and in many instances remarkable. The first thing we noticed was that antbears, famished and unafraid, were walking about in broad day. This unfortunate edentate, among the most highly specialized of mammals as far as its food-supply is concerned, seemed to be in desperate straits. I had here an opportunity of observing for the first time a baby erd-vark out hunting with its mother at midday. The reason that compelled this most nocturnal and shyest of animals to abandon so fixed a habit was immediately apparent. The termites, on which they feed exclusively, live only in hard soil. In the sand dunes there are none. This termite-infested soil was as hard as a rock, and though the erd-vark is the most perfect of mining machines, the hours of darkness were not sufficient for it to reach the nests. Hence was it driven to work in daylight too. Everywhere in the areas of red soil we found its abandoned attempts at shaft-sinking. On another occasion we found its cousin edentate, the armadillo, out in the morning. It was a female and carried a baby of a few weeks old on its back, the tails firmly interlocked.

For the same compelling reason—hunger—most noctural beasts of prey hunted during the day as well as by night. Two leopards raided a small Kaffir stad in the vicinity of our camp and carried off a pig during the early afternoon. The unfortunate baboons apparently never slept at all. Weird and ungainly skeletons they were, fearless through starvation. In normal times no animal is more frightened of the dark than the baboon. Nothing will induce them to leave their sleeping-place before the dawn is well advanced, and they are always careful to be safe on the krans before the approach of night. And here all night long we heard their human-like lamentations as they searched the river banks for food, devouring everything and anything that was remotely entitled to the name.

Where the crocodiles had disappeared to was at first an insoluble enigma. The few stagnant pools in the Limpopo, of course, swarmed with them, but this could not possibly account for the numbers that in rainy seasons rendered every pool in Magalakwen, Palala, Gaul, and the Crocodile dangerous. A possible solution was afforded while digging a hole in the sand for water half-way down the Magalakwen. In the center it had to be at least 6 feet deep in order to reach the water level, and that meant that it had to be at least 25 yards in circumference. Four and a half feet below the surface we came upon a little crocodile, 3 feet long, apparently dead. It was just below the level of the damp sand. Although apparently lifeless the body was quite limp and fresh. We also found a number of small fish known to the bushveld boers as "makriel." They are the northern representative of the well-known barbel of the south. These, too, were apparently quite lifeless. I placed the fish in a bucket of water in direct sunlight and aerated it by pouring a stream from a kettle at intervals from a considerable height. In 10 minutes they began to show signs of life, and in a quarter of an hour they were swimming about in the bucket apparently none the worse for their long sleep. The crocodile we revived within half an hour by placing it in a hole scooped in the sand under the shade of a tree and occasionally pouring a bucket of water over it. The moment it woke to life some strange instinct seemed to compel it to burrow down into the sand again.

Judging from the spoor and from actual observation, it seemed that most of the animals still subsisting in this deadly waste had learned to dig for water in the river-bed. The most efficient diggers were the baboons and the warthogs, and my companion—an old hunter and clever veldman—pointed out an interesting fact to me: that every sounder of pigs was followed by a regular retinue of other animals all day long, apparently for the purpose of using their water-holes when thirst drove the warthogs to the river-bed to dig.

One quite unexplainable thing observed during the height of the drought in certain parts of the Springbok Flats was that the ordinary white ants (wingless) came out of their holes in the middle of the day in vast numbers, and they would lie in the sun in a closely packed ball all day long. The ground next to such a ball was so hot that one could not stand contact with it with the bare hand for above two or three seconds. I was anxious to ascertain the temperature next to them in the direct sun and placed a registering thermometer close against the ball. Unfortunately the scale went to 60° C. (140° F.) only, and the mercury rose to the top of the tube in a few minutes. This terrific sun bath did not seem to injure their etiolated bodies at all. In the cool of the evening they trekked back to their underground nests.

The only animals which suffered no perceptible inconvenience although they also were driven to a change of habits, were *Canis pictus*—the terrible hunting dog. In the middleveld during ordinary times they drive during the day only, mostly in the early morning. But now on account of the terrible heat they hunted at night, and we were often rudely awakened by the noise of their drives. On one occasion a troop drove a full-grown rietbuck ewe right through our camp while we were sitting in the light of a big fire, and pulled her down in the river-bed within 20 paces of our carts. On another occasion a troop drove one of our donkey stallions 2 miles before they captured and devoured the unfortunate animal. Judging from the threatening and fearless attitude of those encountered during the day, I have not the least doubt that they would attack a human being if the least indication of fear and retreat became apparent to them. We once had the pleasure of assisting at the poisoning of a troop that had killed a full-grown male ostrich near a neighboring camp, within a few hundred yards of the tents. This appeared to be a new prey. Several old Waterberg hunters assured me that they had never before heard of wild dogs driving an ostrich, and several of them doubted the possibility of capturing a full-grown healthy male.

The white-headed, vociferous seaeagle, which every visitor to the East African coast will remember, if only on account of its clear triumphant shout high up in the clouds above some estuary, has always been a rare visitor to Waterberg during the early summer. The late Dr. Gunning thought that they were driven inland by storms on the coast. This is a mistake. There can be no doubt that the real reason of their travels so far inland is the drying of the streams which affords them a plentiful food supply easily attained. They follow the course of a drying stream as long as there is any chance of securing fish. We found a large number of these birds on Magalakwen, more than I have ever seen together anywhere. They were apparently caught as in a trap by the drying of the streams behind them. No longer were they noble denizens of the clouds, clean feeders, stooping from the blue to plunge into the fresh clear water—as they are in their native haunts. Here in the middleveld they had become simply vultures, quarreling over fragments of carrion, left by the wild dogs, and picking up putrid crabs and fish along the river banks.

But if I attempt to describe even in outline what the drought has done to the birds of Waterberg, I should need an entire issue of the Journal. However interesting the subject may be, it cannot be gone into on this occasion.

In the presence of this scene of death and desolation it is difficult to cultivate a spirit of optimism. It does not seem possible that enough water can ever again fall to damp or even to cool this parched and cracked earth and to fill these moats of burning sand. Optimism suggests that it is only the great tidal swing of nature exemplified: that we are at the lowest point of the periphery, and that from now onward it must rise steadily up to better things. But at the back of one's mind remains the pessimistic conviction, apparently borne out by every fact observed, that the oscillations of the pendulum are gradually lessening round the dead point.

HOMŒOTIC REGENERATION OF THE ANTENNÆ IN A PHASMID OR WALKING-STICK.[1]

By H. O. Schmit-Jensen, Copenhagen, Denmark.

[With 2 plates.]

REVIEW OF PREVIOUS RECORDS OF HOMŒOSIS IN INSECTS.

The term "Homœosis" (the assumption by one of a series of parts of the characters proper to another member of the series), was first used in biology in 1894 by W. Bateson(1),[2] who in his studies of variation applied it to several cases of meristic, or segmental, variation, in which one member of a meristic series assumes the form or peculiarities characteristic of other members in the same series. In a special chapter of his work, Bateson summarizes all the cases of homœosis in Arthropoda of which he could find records. The four insect records given in this work are here referred to at some length for chronological reasons.

(A) In 1876 G. Kraatz(2) described and figured a specimen of *Cimbex axillaris* where peripheral parts of left antenna were developed into a tarsal joint with two well-developed normal claws, separated by a well-developed plantula. The antenna was otherwise normal, as far as where the club-shaped terminal joint should normally have been, although as a whole it was slightly smaller and thinner than the normal right antenna. Bateson, who had examined this specimen, had nothing to add to the description by Kraatz.

(B) In 1889 Kriechbaumer(3) secured a male specimen of *Bombus variabilis* Schmkn., in Munich, which had the left antenna partially developed as a tarsus. The first two joints of the antenna were normal, the rest were abnormal. From the apex of the second abnormal joint arose a shortened, reddish brown, shiny joint bearing two quite normal claws similar to those on the tarsi.

Bateson further records the following two cases, but remarks that the first must be regarded as doubtful until a more detailed description is made, and that the second may not be a case of homœosis at all.

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[1] Translated by permission from the Danish "Homœotisk Regeneration af Antennen hos en Phasmide, *Carausius (Dixippus) morosus.*" Videnskabelige Meddelelser fra Dansk naturhistorisk Forening i Kjøbenhavn. Vol. 65, pp. 113–134. Copenhagen, 1913.

[2] Numerical references are to bibliography at end of the paper.

(C) In 1840 Saage(4) received from one of his pupils a male *Prionus coriarius* Fabr., with an abnormal thorax. The mesothorax was unchitinized and instead of the elytra carried a pair of fully developed legs, pointing upward and backward and inserted in the exact place where the elytra normally are attached. The metathorax carried normal wings (alæ). The abdomen was no more chitinized than is usual on the upper side under the wings. When the insect attempted to fly, it moved the upwardly pointed legs simultaneously with the wings. It was otherwise normal except that it lacked the scutellum, and that the prothorax carried only two spines.

(D) In 1887 N. M. Richardson(5) reared a male *Zygæna filipendulae* which had five wings but only five legs. The specimen was collected as pupa together with about 700 others in the neighborhood of Cambridge. The posterior left leg was apparently entirely absent and its place was occupied by a fifth wing which was much smaller than the normal hindwings, slightly folded, and differing in color, but in no wise misshapen. The wing was supposed to have been immovable in the live insect. Bateson(1) and Sharp both examined this specimen but could not reach a definite conclusion as to the exact point of the attachment of the extra wing, because they were not permitted to injure the insect by removing the wing or the thick hair covering around its base. Sharp was inclined to believe that the wing was attached along the length of the posterior coxa and described the specimen, on this basis, as an abnormality, which carried a reduced wing instead of a normal leg on its posterior coxa; but he noted that a careful examination might give quite a different result. Bateson reproduced two drawings by Richardson which show the specimen from the underside and the enlarged wing.

Besides these four cases of homœosis in insects, Bateson described a series of cases in Crustacea, but it would carry me too far to discuss these interesting cases or the numerous others since recorded. I shall make an exception, however, of the experimental work by Herbst, which I will here briefly mention.

Herbst(6), who sought to ascertain the rôle which utility plays in the regeneration, asked himself the following questions: Do the eyes of these Crustacea regenerate? and if so, would they also do so in darkness where these organs would serve no purpose and where their regeneration would consequently be superfluous? His results, reached through experimentation, were briefly as follows:

If one of the stalked eyes of a Palæmon, Palinurus, Sicyonia and others is removed, it regenerates as an eye. If, on the other hand, the stalk is removed together with the eye, an antenna-like organ will in some cases be regenerated. This very peculiar difference in the regeneration proved to be due to the fact that the ganglion opticum in these Crustacea is located in the eye stalk and hence was removed together with that. In such species as have the ganglion opticum located nearer the brain and where it consequently is not injured by the removal of the eye stalk, such antenna-like regenerations were never obtained, but an eye was always formed to take the place of the one which was removed. By comparing these regenerations with the normal appendages, Herbst concluded that they could only be regarded as antenna-like formations, which in structure nearest resembled the first pair of antennæ (the antennulæ).

Herbst did not consider these peculiar regenerations to be a result of atavism, and founded this opinion for one thing on the result of the following interesting experiment:

If the ball-shaped apex of a stalked eye in certain species of Palæmon and Palinurus is removed, and the ganglion opticum is then pulled out through the wound by the aid of a pair of forceps, an antenna-like regeneration on the eye stalk results.

Herbst believes it is thereby proved that the same cells in the stalk may regenerate into a new eye or into a very different structure, an antennula, according to whether or not it is influenced by the ganglion opticum.

In 1910 H. Przibram(7) brought together a large number of recorded instances of homœosis and added a few new cases. It will suffice here to mention that he described and in part figured a series of cases in Lepidoptera (Zygæna, Cucullia, Adela) and a single case in the coleopterous genus Prionus. He further tabulated all the cases, both in Crustacea and in insects, in a comprehensive schematic form.

The cases which are of special interest in the present work are later referred to in detail in this article.

It is of great interest to note the regularity, which Przibram pointed out, in the large number of apparently quite unconnected facts which are classed under the name homœosis. He endeavors thereby to give a better understanding of these phenomena and to find a basis for experimental work, without which it would be hardly possible to prove the hypotheses advanced about the formation of homœotic forms.

In 1896 Wheeler(8) divided these phenomena into (*a*) substitutional and (*b*) adventitious homœosis. Przibram adopted this division and added a third, (*c*) the transpositional (translation) homœosis.

These three kinds of homœosis are characterized as follows:

(*a*) Substitutional Homœosis.—(Wheeler: "substitutional homœosis." Przibram: "Ersatz H.," substitution, Homœosis s. str.) This form consists in the supplanting of one appendage ("Gliedmass") by another which normally belongs to a different body segment.

(*b*) Adventitious Homœosis.—(Wheeler: "redundant or adventitious homœosis." Przibram: Zusatz-H., Adventive H., Heterotopie.) This form consists in the addition of a formation, which normally belongs on another segment, at a point which is already supplied with a normal appendage.

(*c*) Transpositional Homœosis.—(Przibram: "Versatz H.," Translation, Heterophorie.) This consists in the transposition of appendages which are absent in their normal positions to points on another segment.

Regeneration is given as the cause of substitutional homœosis; this cause seems definitely proved in many of the cases and is presumably true for the other cases also.

As the cause of adventitious and transpositional homœosis, inherited variations and embryonic abnormalities both seem to play a part.

Substitutional homœosis alone has a bearing on the following and I shall therefore only consider this form and shall briefly mention a few of the rules, which Przibram has proved for this kind of homœosis: Less specialized appendages always supplant the more specialized if these are removed. As the jointed appendages in the Arthropods become less specialized the farther back they are found on the body, this means that the homœotically changed appendages resemble the normal appendages on the succeeding joint. This rule does not hold for the wings, where the opposite is true; a hindwing will thus always be supplanted by a forewing; the opposite has never been observed.

Because regeneration has been proved to be the cause of substitutional homœosis in Crustacea and must be supposed to be the cause also in insects, this kind of homœosis may be regarded as an extreme regenerative Hypotypy.

In the last part of his paper Przibram calls attention to the characteristic, striking tendency to homœosis in certain genera of Crustacea and insects. Of eight cases within the Lepidoptera, six were found in the genus Zygæna. All recorded cases in the Coleoptera (2+1) were in the genus Prionus, and out of six cases in Crustacea five were in the genus Cancer. This is clearly more than accidental.

It is still more remarkable that this tendency can be traced within the different kinds of homœosis; thus only five cases are known where a hindwing has been replaced by a forewing; and four of these cases were in the genus Zygæna, while the fifth was in the closely related genus Adela. Transpositional homœosis is only known in the genus Prionus and similar proportions are found in the Crustacea.

Przibram intends to continue his studies on homœosis experimentally and solicits in his paper material of Prionus, pointing out that as a matter of course these species should be chosen for these experiments in which the tendency to homœosis is found in nature.

In the "Zoologischer Jahresbericht," from 1891 to 1911, I have found the following records of homœosis, which seem to have been overlooked by Przibram in his work(7).

Bateson(9) described a specimen of *Asellus aquaticus* which had the left antennula supplanted by a mandible.

Shelford(10) found a cockroach (probably allied to *Panesthia sinuata* Saus), which by dissection proved to have the right maxilla supplanted by a hard chitinized structure which superficially looked like a mandible. The left maxilla and both mandibles were normal. By closer examination it was found that the abnormal right "maxilla" was made up of four immovable joints. Shelford, without drawing any definite conclusions about the nature of the abnormality, mentions that another species of Panesthia has been found to possess segmented mandibles in the embryonic stage.

Osburn(11) describes a male *Syrphus arcuatus* Fallén (later identified as *L. perplexus* Osburn), in which the large compound eye was absent on the left side; a third antenna was found on this side of the head behind the normal antenna and entirely separated from this, inserted in a separate fossa. The extra antenna was nearly normal but was somewhat undersized and lacked the dorsal seta, the arista. Osburn mentions the experiments of Herbst with the Crustacea and supposes that the eye of the Syrphus had been injured during the metamorphosis and had been supplanted by the antenna.

Przibram (Experimental-Zoologie, 2. Regeneration) later mentions the following case, observed by Tornier, as a probable case of homœosis; Tornier(12) cut off the right antenna on a number of larvæ of *Tenebrio molitor*, which seemed nearly ready for pupation; five of these larvæ pupated seven days after the amputation and the pupæ showed a beginning regeneration of the antennæ. Four of these pupæ developed into imagoes with normal, regenerated antennæ, but the fifth imago showed the following peculiar regeneration: on the tip of the remaining basal part of the antenna, which showed the wound of the amputation on its fourth joint, developed a claw-like formation, which was immovably fixed on the antenna without any joint.

Křiženecký has in a short paper(13) criticized one of the cases of transpositional homœosis recorded by Przibram, but this criticism has no bearing on the present paper.

Before I give my own observations I wish to bring together from Przibram's tabulation(7) such records of homœosis as are of special interest in connection with the present paper, namely, those in which tarsuslike formations have been found on the antennæ.

The cases of tarsus-bearing antennæ in *Cimbex axillaris* and *Bombus variabilis*, Schmkn., recorded, by Kraatz(2) and Kriechbaumer(3) have already been referred to at length in the foregoing.

Klemensiewicz(14) briefly mentions a male specimen of a Zygæn species, which had tarsal claws on the tip of both antennæ; on the righ antenna were found two claws, on the left only one was apparent.

Doumerc(15) has described an abnormal antenna in a specime of *Bombus agrorum* Latreille. As this may be a case of a slightl developed tarsal joint on the antenna, it has been included in Przibram's tabulations, but with a question mark.

The above-mentioned cases of homœosis, which are all classed b Przibram as substitutional, agree in having the tarsal formatio occur on a stalk of antennal joints. In this they agree also with th spontaneous case in Carausius, which is described below.

In this connection must also be mentioned a male *Tenthredopsi nassata*, var., described and figured by Jacobs(16) which, besides th normal antenna on the right side of the head, carried a peculia joined appendage which is inserted beside the second antennal join on the basal antennal joint. Jacobs does not express any opinion o the nature of this appendage. Przibram places the case in his tabulations in the following noncommittal manner: Under the heading "Morphologischer Wert des abnormen Gebildes" and "Ersatz-Zusatz-, oder Versatz-Homœosis," this case is placed relatively a "Fuss?" and "Zusatz?"

Reference must finally be made to the Tenebrio recorded by Tornie and mentioned in the foregoing.

ORIGINAL OBSERVATIONS.

After this review of the literature on homœosis in insects, I shal now discuss my own observations on the homœotic regeneration of th antennæ in a Phasmid, *Carausius* (*Dixippus*) *morosus*. These observations may be of some interest because, so far as I know, it i the first time that the development of a typical homœosis in insect has been referable to regeneration.

The first cause of my studies was a spontaneous case of substitutional homœosis, found in a reared lot of this Phasmid, which i commonly utilized by students of insect biology. This interestin species, whose home is India, propagates itself almost entirely parthenogenetically, at least in captivity.

On this spontaneous case of homœosis I shall record the followin notes:

October 16, 1911, a number of half-grown larvæ of Carausius wer selected for some regeneration experiments. The lot, which consisted of about 50 female larvæ, had been somewhat neglected wit regard to fresh food (rose leaves) and was therefore badly injure *through* cannibalism. This always occurs when a large number o these insects are reared together, for the specimens, which have just cast their skin, become the victims of cannibalism, even if the food supply is kept fresh. Such was the case with the present lot. A number of the specimens were mutilated, being deprived more or less of their legs and antennæ, and it was difficult to find a perfect specimen. One specimen especially attracted my notice. Its right antenna had been bitten off nearly to the base, and on the end of the remaining stump was a small lump, which, to the unaided eye, appeared as a ball of antennal joints, which had grown together. As it would be of interest to observe how this formation would come through the moltings, this specimen was selected among others for a series of regeneration experiments, and its left front leg was amputated at the trochanter. At this date the larva was about 5 centimeters long; it was fed on fresh leaves of English ivy.

On October 24, 1911, it molted. The cast skin was unfortunately devoured overnight. The amputated leg was not regenerated, but the abnormal right antenna had undergone a very interesting change; the "ball" on the end of the antennal stump had developed into a distinct tarsus-like joint with large empodium and with two weak but distinct claws. This peculiar formation was bluish green, which is the color of the blood of the insect, in contrast to the body and legs, which are light green.

Figure 1 (pl. 1), is reproduced from a microphotograph, and shows the head of this specimen, enlarged 7 to 8 times. This photograph, as well as those for figures 2 and 6, was taken after the specimen had been strongly anesthetized with ether (anesthesia by chloroform often produces autotomy of the legs, if the specimen is touched even slightly).

The considerable difference in the two antennæ is very apparent from figure 1. On the abnormal antenna is found, nearest the head, the large basal joint, which has the shape of a cucumber seed, and which carries a short thin stem, consisting of four undoubted antennal joints. This stem carries an oblique, nearly oval joint, thickened at the apex and pointed toward the normal antenna. The claw-bearing joint is attached laterally to this irregular joint, which has several small bud-formed elevations. The claw-bearing joint is nearly spindle-shaped and carries apically a well developed empodium and a pair of weakly developed claws, which lie close to the dorsal surface of the empodium, one on each side of it. The normal relations, in size and position, of the empodium and the claws on the tarsus may be seen in figure 5.

Comparison between the abnormal and the normal antenna shows the different proportions of the parts. The right basal joint is somewhat shorter than the left; the joints which form the stem in the abnormal antenna are considerably thinner than the corresponding joints in the normal antenna; the basal attachment of the right second antennal joint is much narrower than in the left, normal, antenna.

The next molt occurred on November 18, 1911. This time I succeeded in saving the cast skin, which has been preserved in alcohol. At this molt the insect became imago. This stage is reached after six molts. On December 3 began the parthenogenetic egg laying.

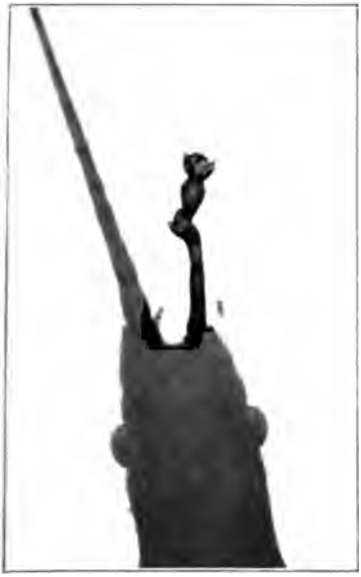
In this stage, the antennal tarsal joint assumed a somewhat different shape, as may be seen in figure 2. The empodium had become reduced to a small round knob, while the claws had grown in size and were curved downward with strongly chitinized brown points. On the underside of the irregular joint, which carries the claw-like joint, are found four empodium-like protuberances, placed 2 and 2, and separated by deep furrows. Comparison of this case with similar ones in the other material proves that these protuberances correspond exactly to the paired plantula found on the underside of the first, second, third, and fourth tarsal joints. This irregular joint with its two pairs of plantulæ is possibly produced by the growing together of two undeveloped tarsal joints.

The length of the abnormal antenna in this full-grown stage is about 6 millimeters. The antenna of a normal imago is about 36 millimeters.

Several details in this spontaneous case of homœosis indicated that it was a regeneration of the right antenna. For example, the thinness of the abnormal antenna in comparison with the stout normal antennæ—a difference in size which is often found after regeneration. The connection between the basal joint and the small second joint indicated that the regeneration probably had its origin from the basal joint. Here also should be considered the conditions under which the larva had lived among a lot of more or less mutilated comrades with definite cannibalistic inclinations.

I therefore concluded that the right antenna had at some time been bitten off just at the end of the basal joint, or rather a little within the end of this joint, and that it had thereafter regenerated into the very peculiar shape above described.

Hence it was natural to begin the regeneration experiment with amputations in the region of the first and second joint and especially in the suture between these joints. I was unfortunately prevented from giving the time and attention desired to these experiments, and was forced to make the amputations by hand with fine scissors, without the aid of a dissecting microscope. By this primitive method I could not always make the amputation just where it was intended—for example, exactly between two joints; often either a little too much or else not quite enough was removed. This condition was of course



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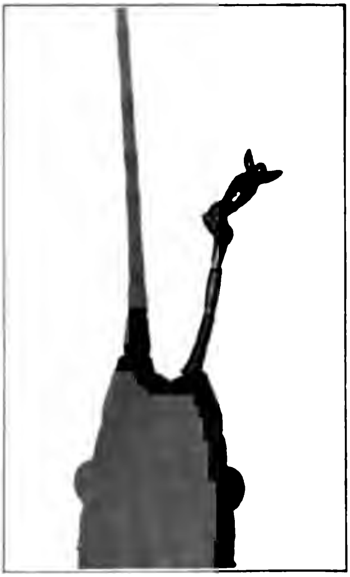

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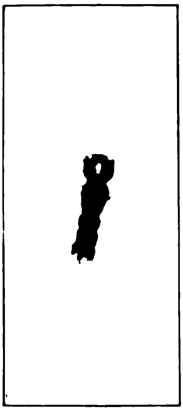
FIG. 1.—Spontaneous case of substitutional homœosis in antenna of larva of *Carausius* (*Dixippus*) *morosus*. Head from dorsal side. Microphotograph taken shortly after the ecdysis, October 24, 1911; magnified 7-8 times.

FIG. 2.—Head of same individual as fig. 1, from dorsal side. Microphotograph taken shortly after the ecdysis, November 18, 1911; magnified 6-7 times.



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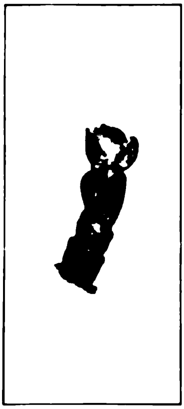

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FIG. 3.—Experimental homœotic formation in a nearly full-grown larva of Carausius. The regeneration, seen from the dorsal side, consists of a claw joint and three small, short tarsal joints without distinct plantula. It grew from the basal joint and thus belongs to group A. Microphotograph from balsam-mount; magnified about 16 times.

FIG. 4.—Distal end of a young regeneration of a leg of a Carausius larva. Microphotograph from dorsal side; balsam-mount; magnified about 16 times.

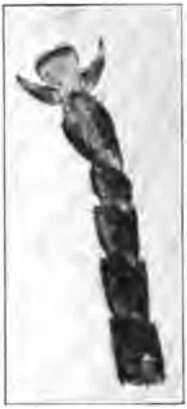

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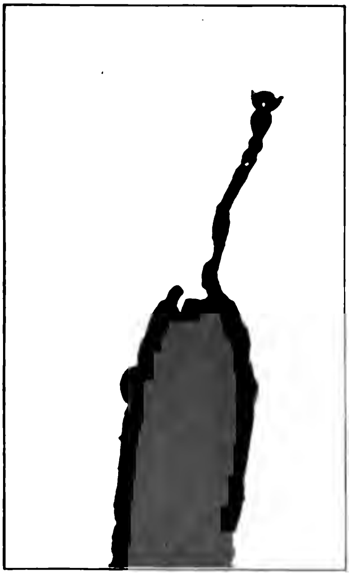
FIG. 5.—Normal tarsus of an imago of Carausius from dorsal side. Of the first tarsal joint only the half is shown. Balsam-mount. Microphotograph; magnified about 16 times.



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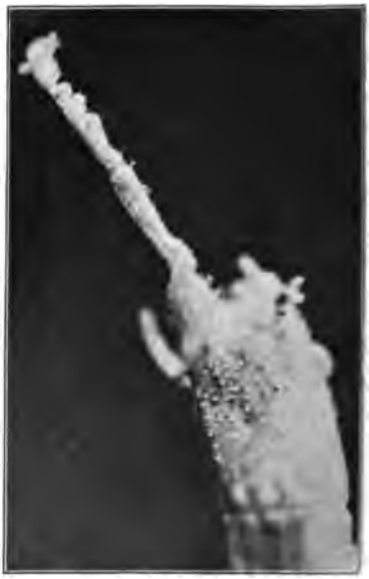

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FIG. 6.—Experimental homœosis in half-grown larva of Carausius. Anterior part from ventral side. Described under group B. Microphotograph; magnified 5–6 times.
FIG. 7.—Anterior part of the body of same specimen as fig. 6, seen from dorsal side. Imago. Microphotograph; magnified 5-6 times.

unfortunate and somewhat lessens the value of the experiments, but as they nevertheless brought some new results, I shall here make record of them.

The experiments began in November, 1911, and lasted until March, 1912. As material I used 50 specimens of newly hatched larvæ of the Carausius and about 60 halfgrown larvæ, all issued from unfertilized eggs. The amputations were made by the unaided eye with a pair of fine scissors; the newly hatched larvæ were anesthetized by ether, as it was difficult otherwise to handle these small, delicate insects. In most cases the amputation was made as exactly as possible in the suture between the basal joint and the second joint, in others both these joints were preserved. In one lot of the specimens the right antenna was removed, in another lot the left, and in a third lot both antennæ were removed. Fresh ivy leaves were used as food and these were daily sprinkled with water. Most of the specimens of this hardy insect thrived well under this treatment, though it must be admitted that the mortality was considerably above the normal—all cases of cannibalism excepted. It was particularly the individuals with both antennæ removed which had difficulty in surviving.

The results of these amputations could be surveyed after a few months. In some cases the insects died, in others no regeneration took place, or at most a small bud appeared on the place of amputation, but a third lot showed regeneration with the formation of not only a single claw joint, but also a series of connected tarsal joints, and in a few of the specimens an additional tibia-like joint.

Figure 3 illustrates such a regeneration in an imago. It will be seen that there is a large claw joint and three other tarsal joints. Comparison with figure 4, which illustrates a newly regenerated tarsus, formed after the amputation of a leg, proved that it is truly a tarsal formation.

Figures 6 and 7 illustrate the most perfect regenerations in which, in addition to the tarsus, a tibia-like part has been formed. These are described below more in detail.

A striking difference between the regenerations I produced in this experiment and the spontaneous case, described above, is that the former are not placed on a stalk of antennal joints, but are emitted directly from the basal joint, or from the second joint. The regenerations developed more and more with each succeeding molt, especially in the young larvæ, which had most changes of skin. The similarity between the tarsus-like antennal joints and the true tarsus became gradually greater as the formations grew larger.

The steps in the development of these regenerations are about as follows: The first molt after the amputation rarely produces any real new growth; the wound is grown together and may show a short bud-shaped outgrowth. After the second molt regenerations are produced consisting of a short stem of undifferentiated tarsal joints and a slightly developed but unmistakable claw joint with its characteristic parts. At this time, the regenerations have not yet reached the differentiation shown in figure 3. At the following molts, the tarsus is further developed; the joints become differentiated and each develops its pair of plantula. The difference in the size of the joints becomes apparent, with the first tarsal joint considerably longer (compare fig. 7) than the following, quite as in the normal tarsus. A large tibia-like joint was further developed in four specimens between the point of amputation on the second antennal joint and the tarsal joints.

My material of these more or less developed homœotic regenerations includes 20 cases. In all these the nature of the regeneration is determined by the presence of a claw-bearing joint or, where this is absent, by the presence of joints supplied with plantula. I have not attempted to diagnose as either antennal or tarsal joints a large number of cases where the regeneration consisted of a short stem of undifferentiated joints, and these cases are consequently not included in the tabulation of the material.

In order to get a comprehensive survey of the material, it is necessary first to note its several imperfections. Specimens of different ages and on which different amputations had been made (within the first and second antennal joints) have been reared together after the amputations. The method of amputation was, as mentioned, imperfect and it is therefore in many cases impossible to determine with certainty the exact place of amputation, and thus draw conclusions with respect to the influence of the place of amputation on the nature of the regeneration. At present it is impossible to determine the age of each specimen at the time of amputation, a factor which is of the greatest importance in the development of the regenerations, as these are dependent upon the molts like the rest of the organism.

However, the place of amputation can be determined approximately in most cases. As all of the amputations in these experiments were made on or between the first and second antennal joints, I have relied in these determinations upon the relative size of the regenerated part and the joint from which it has grown. Due to its larger diameter, the second joint covers the entire apex of the basal joint, while the more slender regenerations are generally attached with a much smaller base to the broad basal joint. A comparison with a remaining normal antenna is naturally a considerable help in these determinations (pl. 1; figs. 1, 2).

In the arrangement of the material, I have given special attention to the insertion place, structure, and size of the regenerated appendages.

The material may be divided into two groups, according to the place of amputation:

Group A.—In this group the amputations were made in the suture between the first and second antennal joints, or possibly encroaching somewhat on the first joint.

All the regenerations in this group, which includes 14 out of 20 cases, are small, only 0.5 to 2 millimeters in length. The number of joints varies from one to four. The regenerated part is often badly crippled, curved, crooked, or spiral. Most frequently one disproportionally large claw joint is found together with two or three small, plantula-bearing tarsal joints. A claw joint may often be found in this group without the presence of plantula on the other joints and vice versa.

Nearly all the cases in this group are in imagines, hence the possibility is not entirely excluded, that the defective regeneration is due to the fact that the amputation was made in a later stage and that therefore fewer molts have intervened. Considering the dwarfed proportions of most of these formations I regard it however, as improbable that further developments could have taken place through intermediate forms to the very perfect regenerations found in group B.

Group B.—In this group the amputations were made in the suture between the second and the third antennal joint or possibly encroaching somewhat on the second joint.

While all the cases within the first group are of nearly similar structure and degree of development, this second group, which contains a minority consisting of six cases, must be divided into two subgroups, according to their different composition.

In the first of these subgroups, which includes four cases, fall the largest and highest developed regenerations within the material under observation. These consist each of four well-developed tarsal joints and one large unjointed tibia-like segment, inserted between the place of amputation and the first tarsal joint. The most striking of these cases is shown at different stages in figures 6 and 7. A description of this interesting regeneration will explain the structure of these specimens better than figures.

With the second antennal joint, which presumably has been partly amputated, as a base, is found a tibia-like joint, 2 centimeters long, which is constricted at its base and gradually becomes thicker outwardly. It possesses longitudinal ridges, covered with very small, stiff, dark brown hairs, exactly as found in the normal tibia. This character together with the position of the joint, next to the tarsal joints, presumably justifies the characterization "tibia-like." It should be mentioned that the antennal joints have only scattered hairs.

Connected by a joint with this short tibia-like structure is the long, slender first tarsal joint, which is followed by two short tarsal joints; these three joints possess on their plantal surfaces each a well developed pair of plantula. On the fourth well-developed tarsal joint is found a large empodium and two strong curved claws. The entire regenerated part is about 8 millimeters long, of which the tarsal part measures 3.7 mm. The normal tarsus in an imago measures with its five joints about 6 mm.

Of the other specimens within this subgroup, two were nearly full grown and one was half grown.

The other subgroup contains only two regenerations, both found in full-grown specimens. They differ from the other examples within this group mainly by the absence of the tibia-like segment. They consist only of four well-developed tarsal joints, which in size are equal to the corresponding joints in the cases described above.

It is possible that these regenerations under favorable conditions might develop further and acquire the tibia-like segment, which alone differentiates them from the other cases in this group.

It should be mentioned in this connection that the antennal tarsi, like the regenerated tarsi on the legs, at most consist of four joints, while the normal tarsus is five-jointed.

Group C.—This group is not represented among the material produced in these experiments, but contains only the spontaneous regeneration, described in the foregoing. This case is sharply differentiated from the types just described by the possession of a stem of antenna-like joints. Nowhere else in my material have I found any case in which I have been able to detect the presence of a stem of antennal joints bearing the tarsal joints.

Another division of the material into two groups may be made—for example, on the different composition of the regenerated appendages; the first group containing such specimens which consist only of tarsal joints and the other including such which possess a tibia-like joint in addition.

Such a division will not coincide with the first division made on the different places of amputation, on account of the grouping within the group B, above defined. This may be merely a result of the manner in which the amputations were made and of insufficient material. It has already been noted that further experimentation may prove that the two subdivisions within group B may represent the same type in different stage of development.

With regard to a possible relation between the structure of the regeneration and the place of amputation, I shall confine myself to giving the general impression I received during my studies: Amputations across the basal joint or between this and the second joint produce dwarfed, slightly developed homœotic regenerations, while amputations across the second joint or between the second and the third joints cause strong well-developed homœotic regenerations. It is possible that quite different results may be reached by more careful experimental studies of larger material, which shall obviate all such disturbing factors as occurred in my material (the different ages of the larvæ, the primitive method of amputation, etc.).

Since the termination of these experiments with regeneration, I have made numerous different amputations, by the aid of very fine scissors and a dissecting microscope, on larvæ of Carausius, which had been anesthetized with ether. Among the several places which I selected for amputation in these series of experiments may be mentioned the place where the antenna is inserted on the head, the middle of the basal joints, the end of the second and the third joint and others. These amputations can be easily made with considerable precision.

I was unfortunately forced to abandon these series of experiments, as well as other preliminary, similar experiments with two other Phasmids, *Bacillus Rossii* Fabr. and *Diapheromera femorata* Say, before the regeneration had taken place.

More thorough experimental work on this problem on a large scale is badly needed, but interesting aid to the understanding of these phenomena would surely result from historical study also. In this connection must be mentioned the gratifying accord between the experiment and the anatomical study in a similar field by C. Herbst, which has been referred to in the foregoing.

Leaving herewith my experimental results to be further worked out by others, I shall in conclusion briefly mention such references in the literature on the Phasmidæ, as are of interest in this connection. There are not many, as apparently little work has been done with antenna-regeneration in this group of insects, in which the study of regeneration at one time caused particular interest.

R. dé Sinéty(17) has amputated the antenna in *Leptynia attenuata* with the result, that regenerations were produced with 2 to 4 joints. In one case, where one antenna was completely removed, a small four-jointed antenna was regenerated, in which the basal joint was only half as long as in a normal antenna.

R. Godelmann(18) amputated the antennæ in *Basillus Rossii* Fabr. Of the results he only mentions that the regenerations had a slow growth and never reached even approximately normal size.

Otto Meissner(19) who has done considerable work with the biology of *Dixippus morosus* Br., briefly mentions that regenerated antennæ often are shorter than the normal, but that they may contain nevertheless the normal number of joints.

It is apparent that none of these authors has observed homœotic regeneration.[1]

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[1] I wish to express my sincere thanks to Hr. Docent Mag. Scient. R. H. Stamm, from whom I have received valuable help in this work and who, for example, placed the library of the histological-embryological laboratory in the Copenhagen University at my disposal.

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LATENT LIFE: ITS NATURE AND ITS RELATIONS TO CERTAIN THEORIES OF CONTEMPORARY BIOLOGY.[1]

By PAUL BECQUEREL, Sc. D.

I. GENERAL OBSERVATIONS.

Although the study of latent life holds an unimportant place in most of the standard works on biology, yet it is none the less one of the most widespread phenomena of the living kingdom. We meet it everywhere that germs exist. And since germs are continually emitted in considerable quantity, even more by plants than by animals, there is not a piece of ground on which we tread nor the smallest quantity of air that we breathe which is free from them.

Not only can the spores of fungi, bacteria, algæ, mosses, and of ferns, the myriads of grains of pollen from flowers, the seeds of phanerogams, the cysts of infusoria, the eggs of certain crustaceans and insects, pass into a state of latent life, but likewise animal tissues, and even some perfectly developed forms of life called reviviscents, as certain species of algæ, mosses, lichens, rotifers, arctisca, and nematodes.

In that condition of repose, these germs or beings may escape the harsh necessities of active life, better resist dryness, cold, or heat, are more easily carried away by the currents, winds, or other causes, finally to await for several years the return of conditions favorable to their development.

II. THEORIES AS TO THE NATURE OF LATENT LIFE.

But what is the true nature of latent life? Is it apparent death in which all the vital functions are suspended; is it a relaxed aërobic life demanding gaseous exchanges with the atmosphere, or is it a very sluggish, intercellular anaërobic life? These are questions which since the beginning of the eighteenth century have engrossed the attention of eminent naturalists, have incited numerous experiments, and which at this moment provoke interesting controversies.

We owe to Leeuwenhoek (1701), the founder of micrography, the first observations on reviviscent animals, the arctisca or water bears, and rotifers of the roofs and gutters. That author observed with great astonishment that these little beings may remain dried up for five months amid moss and dust without showing the slightest trace of life and then, when moistened, resume their vital functions.

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[1] Translated by permission from Revue générale des Sciences pures et appliquées, vol. 25, No. 11, Paris, June 15, 1914.

In 1743 Needham made analogous observations upon the nematodes from musty wheat. But the most interesting experiments upon these organisms have been chiefly those of Baker and Spallanzani.

Baker, working with nematodes (anguillula), succeeded in bringing them to life 28 years after their desiccation. Since we know that the life cycle of these minute beings does not exceed 10 months, it is thus proved that their life has been strikingly prolonged by this procedure.

On the other hand, Spallanzani verified the observations made by Leeuwenhoek on the rotifers. After having dried and preserved them for three years, he found that they returned to life when placed in water. All these experiments amazed the public of that period. It was at that time believed that these beings had the power of resuscitation. The extraordinary properties of these animalculæ having been doubted in the nineteenth century, Doyère and Davaine, from 1840 to 1860, studied the subject very critically. Their experiments, confirmed by Gavarret, but bitterly contested by Pouchet and Pennetier, were the subject of very spirited discussions. In fact, at that time two rival theories, vitalism and organicism, were sharing the approbation of physiologists. Some, and they were in the majority, considered life as a mysterious principle of action which animates matter and sets it in motion. The others saw in life only the result of the organization of a special complex substance, merely the manifestation of the activity of organized matter.

In order to show the soundness of their conception of the question, those holding the latter view called attention to the phenomena presented by the revivified animals, notably in the experiments of Doyère and Davaine, in which they believed that they had seen a very clear example of an arrest of the functions of an organism and of their starting again under the action of a physical phenomenon, namely, the imbibition of water.

Organized matter therefore needed only a vital principle to resume activity. In the Société de Biologie the strife between the two factions was so earnest that to put an end to discussion it was decided to repeat the experiments before a committee of scientists which included Balbiani, Brown-Séquard, Dareste, Guillemin, and Robin, and was presided over by Broca.

Before this committee it was then established: First, that there is no appreciable life in the inert body of reviviscent animals; second, that the bodies preserve their revivifying property in conditions incompatible with every kind of functioning life, as for example, for

82 days in a dry vacuum, and in free air for 30 minutes at a temperature of 100° C.

Some time later, Paul Bert in his researches upon the inherent vitality of tissues, corroborated this point of view by some interesting experiments. He showed that rats' tails dried for eight days, then kept for two hours in a temperature of 99° C., and grafted four days afterwards, resumed their vitality at the end of a month. About two years later, Claude Bernard, in his admirable lessons on the phenomena of life common to plants and animals, resumed the study of reviviscence and applied it to the vegetable kingdom.

In order to characterize the state of repose in which the seeds exist before germinating, he coined the term "latent life" and he gave us the following theory:

> The latent life of seeds is potential. It exists ready to manifest itself if suitable exterior conditions are supplied, but there is not the least manifestation if these conditions are lacking.
>
> It would be wrong to think that the seed, in this case, possesses a life so attenuated that its manifestations escape observation because of the very degree of this attenuation. That is true neither in theory nor in fact. In theory, we know that life results from the coalition of two factors—the one external, derived from a cosmic world; the other internal, derived from the organism.
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> It is a coordination impossible to separate, and we should understand that in the absence of one of these factors the being could not live. It no more lives when the factors exist under unsatisfactory conditions than when they exist alone. Heat, humidity, and air do not constitute life; no more does the organism. In fact, we see some seeds preserved for years and for prolonged periods which after such long inaction, can germinate and produce a new plant. If they had a sluggish life, that ought to exhaust it. But it is not exhausted.

From the moment that it was proposed, this conception of latent life has had many supporters who have strengthened it by the establishment of new facts. Thus the resistance of seeds, of spores of bacteria and mushrooms to the action of a vacuum, of irrespirable gases such as nitrogen, carbon dioxide, carbon monoxide, and chlorine, the conservation of the germinative power in liquids such as mercury, alcohol, ether, and chloroform, as shown through numerous experiments by Giglioli, Detmer, Romane, de Candolle, Kochs, Jodin, Ewart, Kurzvelly, Maquenne, to cite only the principal authors, demonstrate in an apparently indisputable manner the reality of suspended life.

In spite of these facts, however, other physiologists have nevertheless continued to defend a theory directly opposed to it; that of the continuity of the vital phenomena, a doctrine according to which latent life is but a life relaxed.

Among the most eminent supporters of this view we may cite Van Tieghem and Gaston Bonnier, whose researches on the latent life of seeds have become classic. These scientists having allowed separate lots of seeds to remain two years in confined air and in carbon dioxide, perceived in the first medium that there had been an absorption of oxygen and a throwing off of carbon dioxide, and in the second medium asphyxiation. From this they concluded that respiration takes place in latent life and when it is not possible, the organism perishes; consequently, life in the embryo can be only relaxed. These conclusions allayed certain doubts as to the early experiments of Doyère and Davaine. This is why Lance in 1896 took up the study, confining his researches to arctisca.

Contrary to the claims of the committee presided over by Broca, he himself affirmed that the coming to life of these beings is not a resurrection:

> The arctisca of the roofs adapted to desiccation lose their power to revive when after desiccation they have been plunged into a gas, unsuited to support life, such as carbonic and sulphuric. When they find respiration impossible, they die; their latent life is then a relaxed life.

We have therefore to deal with two contradictory hypotheses, apparently based upon facts equally conclusive:

Is the relaxed life a more exact conception of the nature of latent life than the suspended life?

Must the one completely exclude the other or is each one partly true? These are questions which I have tried to elucidate and to which we shall now turn our attention.

III. THE IMPERMEABILITY OF THE TEGUMENT OF CERTAIN SEEDS.

When in 1904 I undertook these researches, limiting myself entirely to the latent life of seeds,[1] I asked myself if the prevailing contradictory opinions were not due to errors in interpretation of certain experimental results. For instance, were the embryos of the seeds really in contact with the media tried—confined air, irrespirable atmosphere, nitrogen, carbon dioxide, mercury, alcohol, chloroform, and ether? If their tegument had been impermeable, might it not have protected them against the various media that it was intended to subject them to? That was an important point, to which the greater part of my predecessors paid too little attention.

It was therefore very necessary to find a means for determining the permeability of the teguments of the seeds which were most used in the above-mentioned experiments. I employed a very simple apparatus: A barometric tube closed at one end by a portion of the tegument to be experimented upon, then filled with mercury with all the usual precautions, and inverted in a dish of mercury. The variations of the level of the mercury of this pseudo-barometer which terminated in a vegetable membrane, compared with the variations in the level of the mercury of another tube of the same kind, prepared in the same manner, but closed at one of its extremities, indicated under what conditions and at what rate the gas passed through the teguments.

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[1] Researches on the latent life of seeds (1904–1907). Annals of Natural Sciences, Botanical, 9th series.

In this way I was able to determine that the tegument of most of the seeds of Leguminosæ, such as that of the lupine and honeylocust, when it reached a certain degree of natural desiccation,[1] proved itself to be for two years impermeable to air in all its parts, even in those containing the hilum and the micropyle. The teguments of these seeds do not permit gases to pass through them under the laws of diffusion except when they are moistened with water.

On the other hand, desiccated embryos of these same seeds act like porous bodies. Gases pass through them according to the laws of effusion. The tegument of the same species is equally impermeable to liquids, such as absolute alcohol, ether, and chloroform, which readily penetrate the embryos after decortication.

These results apply not only to the seeds of many species of the family Leguminosæ, but likewise to those of certain Cruciferæ, Malvaceæ, Labiatæ, Linaceæ, and Cistaceæ. They justify the reservations that I had made concerning the greater part of the experiments of my predecessors, for, in showing that the embryos protected by their impermeable teguments were not submitted to the action of the media employed, they nullify in part the deductions that had been drawn from them to explain the nature of latent life.

I was thus led to repeat on seeds with the permeable tegument either perforated or removed, the experiments of some of my predecessors. I thereupon ascertained that, contrary to their assertions, absolute alcohol, chloroform, and ether, instead of preserving the embryos of seeds, kill them when no longer protected by their teguments. On the other hand, the fact of the impermeability of their tegument rendered very improbable the interpretation that had been placed upon the gaseous exchanges of certain seeds.

With seeds of lupine, peas, castor beans, and beans, taking into account the rôle of their tegument, I repeated the experiments of Van Tieghem and Gaston Bonnier. Several comparable lots were prepared, some containing only decorticated seeds, others consisting only of the teguments of these seeds, and finally some seeds protected by their teguments. All these lots were placed in the confined and dry atmosphere of tubes inverted upon mercury, some placed in full light, others in darkness.

Six months later, having made analyses of these confined atmospheres, I found that the gaseous exchanges had been greater in the light, and that the isolated teguments of the seeds had absorbed more oxygen and given off more carbon dioxide than the embryos.

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[1] Degree of desiccation which is normally attained in the ordinary conditions of conservation of seeds.

Certain teguments taken from castor beans had given off in darkness 1.61 per cent of carbon dioxide and had reduced the quantity of oxygen to 15 per cent while the separated embryos from which they had been taken, placed with their endosperm in the same conditions, had not changed their atmosphere at all. If the gaseous exchanges of these seeds protected by their teguments had been interpreted as true respiration, one would have arrived at the paradoxical conclusion that the teguments composed of dead cells respired, while the embryos with their endosperm ready to germinate, having neither absorbed nor thrown off the least particle of gas, were dead.

The results obtained with several kinds of decorticated seeds, such as those of peas, beans, and lupine, in their natural state of desiccation, that is, still containing a certain quantity of water, convinced me that after a certain time in darkness they absorb traces of oxygen and throw off traces of carbon dioxide. There must therefore be in the embryos of those seeds which were not protected by their teguments and were in their natural state of desiccation extremely slight gaseous exchanges.

IV. THE NATURE OF THE GASEOUS EXCHANGES IN SEEDS.

But are these gaseous exchanges that are indicated in the case of the decorticated seeds in their state of natural desiccation really caused by a true respiration, the result of a kind of relaxed life for which the oxygen of the air is absolutely necessary? To find this out, I rendered the respiration of the embryo impossible by depriving it by means of a vacuum of its internal atmosphere confined in the intercellular spaces and in the cells themselves which intercommunicate so readily through the punctures of their walls. The embryo was then placed for a greater or less time in contact with irrespirable media. Treated thus, peas with their teguments perforated, and deprived of their internal atmosphere, remained a year under the mercury and grew perfectly after the experiments. Seeds of beans, peas, castor beans, and wheat after decortication were kept in darkness in an atmosphere of nitrogen without giving off any trace of CO_2 and without losing their power of germination.

Other seeds of lupine, lucern, peas, clover, mustard, pumpkin, buckwheat, and pine, and grains of wheat and oats, after perforation of their tegument were kept for eleven months in pure and dry carbon dioxide without suffering any injury. Finally, desiccated seeds of garden cress, lucern, and peas, and grains of wheat with the tegument perforated, were inclosed for two years in vials in which a nearly complete vacuum had been obtained, without injury to their germinative power.

These are new results, all agreeing, which are opposed to those classic experiments on which dependence is still placed to show the existence of a respiration in seeds. These results afford a proof that the gaseous exchanges demonstrated by Van Tieghem and Bonnier are not due to an attenuated respiration, but to a simple chemical oxidation of the surface of the tegument or of the embryo.

The generally accepted conception of the latent life of seeds must be modified. It is an extremely sluggish, intracellular, anaërobic, or else a suspended life. How is one to choose between these two hypotheses?

V. LONGEVITY OF SEEDS.

If the life of seeds in nature were entirely suspended, if all the protoplasmic functions of assimilation and of disassimilation were completely arrested, as claimed by Claude Bernard, their germinative power should be unlimited. This is what many naturalists believed when they were told of the extraordinary case of the longevity of grains of wheat inclosed for more than 2,000 years in the tombs of the Pharaohs, which, once sowed, would have germinated. But it is now known that the good faith of these scientists was imposed upon. Mixtures of authentic and recent grain were sold to them. This fraud, by which such botanists as Alphonse de Candolle and Decaisne were not deceived, was unmasked by M. Maspéro. This eminent egyptologist never succeeded in germinating the grains of wheat which he himself collected in the tombs of the Pharaohs. Furthermore, the study of these grains made by Ed. Gain showed that their embryos were partially destroyed; when they were moistened, they were transformed into an amorphous pulp.

On the other hand, no confidence can be placed in the story of seeds from Roman sepulchers or the graneries of Cæsar, Argau, or Herculaneum, or from Merovingian tombs or excavations. Too many flaws in the evidence, ignored by the investigators, destroy every basis for their claims. Only experiments made with specimens of which the time of harvesting the seeds and the date of their arrival in the laboratory are known can give us acceptable evidence.

Already, in 1831, Alphonse de Candolle had carried on researches with 368 kinds of seeds preserved for 14 years in sacks. Many species of Leguminosæ and Malvaceæ had conserved their germinative faculty. I resumed the work of that learned naturalist, extending it to 500 kinds of seeds belonging to 30 of the more important families of monocotyledons and dicotyledons. The seeds came from the seed collection of the Muséum d'Histoire Naturelle of Paris. The time of their collection, carefully verified, varied between 25 and 135 years. Four families furnished germinations: the Leguminosæ, the Nelumbonaceæ, the Malvaceæ, and the Labiatæ.

Twenty of these germinations came from seeds 28 to 87 years old. Among the Leguminosæ the oldest species were *Cassia bicapsularis* of 1819, *Cytisus biflorus* of 1821, *Leucæna leucocephala* of 1831, and *Trifolium arvense* of 1838. The seeds which germinated at such an age were covered with a very thick tegument, whose impermeability to gases was checked experimentally in the case of the Leguminosæ and the Nelumbonaceæ. In this way it was proved that some seeds conserved their germinative power from the epoch of the Restoration to our time without their embryo having gaseous exchanges with the atmosphere. The tegument of these seeds preventing through the years the oxidation of the substances in reserve and their hydration under the action of the humidity of the atmosphere, did much to assure them this remarkable longevity.

Nevertheless, this longevity is not unlimited. The germinative power always diminishes with time. Macrobiotic seeds, to use the picturesque expression of Ewart, who has written an excellent monograph on them,[1] do not keep their germinative power much beyond a hundred years.

The claim of Claude Bernard that the latent life of seeds, under natural conditions of their preservation, is not exhausted, rests on inexact data, and the undeniable fact of the aging of commercial seeds seems to refute it. When, however, you carefully examine the significance of this fact, it is not a positive proof against the theory of suspended life. The loss of the germinative faculty of the seed may very well be caused by physico-chemical phenomena which may not apply to those of an extremely sluggish life.

Why should not the protoplasm of the cells, when life is suspended, become decomposed in the course of time under the influence of the humidity and the oxygen accumulated in the intercellular spaces? What would prevent its comporting itself like inert substances which gradually lose their original properties, their potential energy? With time liquors are modified, a spring tends to wear out, powder ages, and yet in these substances there is no retarded life!

VI. THE DEHYDRATION OF GERMS.

However that may be, since it is impossible to prove that a seed preserved under ordinary conditions is in a state of suspended life rather than in one of relaxed life, the problem might perhaps be solved by placing the seed under artificial conditions such that, without affecting its germinative power, its life may be temporarily arrested.

All the writers who are engaged with this subtile problem are of the opinion that the water and the gases inclosed in protoplasm are the cause of its decomposition. A seed in a state of natural desiccation always contains a quantity of water ranging from 0.5 to 20 per cent of its weight. But is it possible, without injuring its germinative faculty to deprive it completely of this water? Relying upon experiments by numerous investigators, particularly upon those of Schröder and Ewart, it was believed until recent years to be impossible to withdraw all the water from the protoplasm of seeds without killing them. In fact, Ewart had ascertained that as a general rule the most resistant seeds lost their vitality when their percentage of water fell below from 2 to 3 per cent of their weight. This had led him to believe that the protoplasm of seeds in its state of natural desiccation must have a chemical composition very different from that of protoplasm fluid in a condition of active life. According to this new theory the chemical composition of the protoplasm in latent life would correspond with the chemical equation proposed by Loew for certain albumins. In that instance there was obtained by polymerization of aspartic aldehyde with the addition of hydrogen and sulphur, a proteid which finally gave an albuminoid, whose formula, $C_{72}H_{112}Az_{18}SO_{22}+2H_2O$ contains 2 per cent of water.

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[1] Ewart, On the longevity of seeds. Proc. Roy. Soc., Victoria, vol. 21, 1908.

This conception of protoplasm from which you can not draw out its 2 per cent of water without decomposition, appears to me too simplistic or one sided, as much from the standpoint of physics as from that of chemistry. Besides, this formula does not include the greater part of the chemical elements, metals, and metaloids which are absolutely necessary for the constitution of the nuclei of cells and the formation of a protoplasm capable of life. Consequently it does not correspond to the reality of experimental facts, for though certain kinds of cells do not endure a prolonged desiccation, the result is not the same with many other cells.

Ewart was unable to ascertain this because he employed a very defective method of desiccation—that of the sulphuric-acid desiccator, a process which has the great objection of often altering the protoplasm entirely in desiccating it. Moreover, as Maquenne, the learned physiologist of the Muséum d'Histoire Naturelle, has demonstrated, for completely drying the seeds there is only one effective method and that is the employment of a vacuum for several months at a temperature of 40° to 45° in the presence of anhydrous BaOH.[1]

This process is more efficient than that of the oven at 110°C. which is employed in the method of dry weights. Moreover, if, as I have advocated, the precaution is taken of decorticating the seeds or of perforating the impermeable tegument, desiccation can be obtained more rapidly and more actively, so that there is no releasing of vapor in the vacuum nor loss of weight; and, besides, the germinative power of the seeds thus treated is not destroyed. Maquenne has proved this in the case of grains of wheat, seeds of parsnip, and castor bean, and myself for seeds of pumpkin, peas, and buckwheat, which lost 10 to 14 per cent of their weight of water.

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[1] Maquenne: C. R. Acad. des Sc., t. 134, p. 1234; t. 134, p. 208.

Now, are seeds artificially dried more readily altered, or do they conserve longer than others their power of germination?

According to my investigations, the seeds of pumpkin, castor bean, and beans, thoroughly dried, preserved in darkness in a dry atmosphere of air or nitrogen are not oxidized. I have been unable to detect by analysis the slightest indication of absorption of oxygen or release of carbon dioxide.[1] Likewise, according to Maquenne, dried parsnip seeds preserved for two years in a vacuum had suffered no loss of their germinative power, while seeds preserved in the open air as checks had been dead a long time.

These parsnip seeds, losing their power of germination at the end of six months, had therefore, as a consequence of their dehydration and their protection from oxidation, quadrupled the duration of their latent life. Upon the basis of these results, Maquenne concludes that cellular respiration is arrested in a vacuum, and that under the influence of desiccation the seed passes from a state of relaxed life to a state of suspended life in which vegetative functions cease to be performed. This conclusion, which is supported by all my above-mentioned researches, appears to agree well with the facts. But many physiologists, partisans of the theory of the continuity of vital phenomena, are unwilling to accept it.

They oppose the following objections:[2]

> In this matter of gaseous exchanges, especially if they are intracellular, how can you prove whether they are slight or negative? What leads you to believe that your methods of analysis are satisfactory evidence? There where your judgment hesitates, your theory affirms. It maintains a priori that the process of assimilation neither suffers, nor stops, nor begins again, but follows a continuous march.

Obviously it is very difficult to prove a complete arrest of the phenomena of life in the organism in a state of latent life. However, it must be acknowledged that the vacuum and the dehydration, carried to the extreme limit, should signally retard the exchanges of matter and energy in the protoplasm. If to these two conditions, already very influential, there be added a third, that of low temperatures, will not the suspension of life be really accomplished experimentally?

VII. THE INFLUENCE OF LOW TEMPERATURES.

The influence of low temperatures on seeds and on spores of bacteria has been studied for 30 years by a number of investigators, chief among whom are Raoul Pictet, Casimir de Candolle, Brown and Escombe, Dyer, and MacFadyen. These scientists have proved that seeds and spores in their state of natural desiccation endure, without perishing, temperatures as low as 190° to 250° below zero. I myself in attempting to ascertain the influence of the state of hydration, of decortication, and of gaseous reserves of the seed, have obtained analogous results. The investigators above mentioned, believing that physical and chemical phenomena are completely suppressed by low temperatures, have thought that the latent life of seeds and germs plunged into liquid air or hydrogen must be a completely suspended life. But this opinion should be accepted with some reserve. Certain chemical reactions may still take place at low temperatures. Have not Dewar and Moissan shown that solid fluorine in contact with liquid hydrogen is combined explosively at 250° C. below zero? On the other hand, Svante Arrhenius[1] does not now admit the suppression of chemical reactions at that temperature. He considers that the chemical reactions especially connected with the loss of the germinative power of seeds must be much retarded by cold. Upon the basis of the experiments of Nyman and Madsen in which the spores of anthrax are shown to develop twice as rapidly when the temperature is increased 10°, the eminent Swedish physicist formulated an ingenious hypothesis according to which the retardation of life should be twice as great if the temperature is lowered 10° C. According to this rule the germinative power of spores would diminish no more during 3,000,000 years at 220° below zero than during a single day at 10° above zero.

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[1] Paul Becquerel: Sur les échanges gazeux des graines. C. R. Acad. des Sc., Dec. 10, 1906.

[2] Dastre, La vie et la mort, p. 226 (Flammarion, Paris). M. Dastre, whom I have consulted on this subject, now accepts my point of view.—(Note of M. P. B.)

If we accept this calculation and apply it to macrobiotic seeds which live a hundred years at a temperature of 10°, their latent life, provided it could be kept at a temperature of 220° below zero, could be prolonged for two hundred billions of years. This is a number which surpasses any which is conceded for the duration of life on the surface of the earth, and even for the period of the evolution of our solar system.

If the physical and chemical phenomena of life are thus retarded, we concede that we could not detect it experimentally.

But since in all the experiments with low temperatures upon which Arrhenius relies, it is a matter of germs in the state of natural desiccation, containing consequently from 5 to 12 per cent of their weight of water, it is interesting to ask what would happen if we were to experiment with dried seeds placed in the most complete vacuum and submitted at the same time to the lowest temperatures. With this in view, with the valuable cooperation of the learned physicist of Leyden, M. Kammerlingh Onnes, who very kindly placed at my disposal the resources of his excellent cryogen or refrigerating laboratory, there were submitted for three weeks to the temperature of liquid air and then for 77 hours to that of liquid hydrogen at 250° below zero, decorticated seeds previously dried, of lucern, mustard, and wheat, and spores of Mucor, Rhizopus, and Aspergillus, and of various bacteria inclosed in sealed tubes in which the most complete vacuum possible had been secured.[1]

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[1] Svante Arrhenius: L'évolution des mondes (translation by Seyrig), p. 138.

All these seeds at the end of one year, and the spores after two years in the vacuum, showed a high percentage of germination.

In this particular case in which the cell was deprived of water and gas, in which its diastases were desiccated, and the protoplasm lost its state of colloid solution, at least while they were under the simultaneous influence of desiccation and low temperatures, one can hardly say that latent life is relaxed life.

Life without water, without air, without gaseous exchanges, without colloid molecules, in suspension in a liquid, appears to me paradoxical. The vital phenomena of assimilation and of protoplasmic disassimilation being rendered temporarily impossible, I believe that the real latent life such as Claude Bernard conceived it, that is to say, the suspension of life, under these particular conditions has been realized.

VIII. THE PHYSIOLOGICAL CONSEQUENCES OF THE SUSPENSION OF LIFE.

If that is the case, the law of the continuity of vital phenomena is dealt a severe blow. In fact, the phenomena of life, which since their appearance on earth have been transmitted without interruption from generation to generation during millions of centuries, with only occasional retardation in the germs, have now for the first time, under the influence of exceptional conditions, been interrupted in certain cells, without injury to their power of resuscitation. Moreover, these facts demonstrate that one can not confound an organism wholly inert during latent life with a dead organism. Although on examination a dried seed and a dead seed appear identical, there is a great difference between them. The protoplasm of the dead seed has undergone an irrevertible chemical modification, such that if it be placed in conditions favorable for its development, none of the physical and chemical phenomena of assimilation and disassimilation can longer be produced.

On the contrary, the protoplasm of the seed in latent life, under the combined action of the vacuum, desiccation, and cold has received only a physical modification which has in no way altered its chemical composition. It is a revertible modification which it has undergone, since if there be restored to it water, gases, and the proper temperature, its substances again take on their properties and all the physicochemical phenomena of its vital activity reappear. The experimental proof of the interruption of life without destroying its power of resuscitation and without leaving any mark to make one suspect the existence of a limit to its prolongation in the case of both seeds and spores, is, moreover, a good argument against certain neovitalistic theories. It demonstrates the actuality of the strong persistence of vital phenomena and exposes the unstableness of the basis of the definition of life accepted and promulgated by such scientists as Grasset, Bundge, Reinke, and Lodge.[1]

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[1] Paul Becquerel: C. R. Acad. of Sc., Apr. 19, 1909, and May 30, 1910.

According to the definition of this last author, in his little work, La vie et la matière, life is a particular force, "a special directive power issuing from a world in which physics and chemistry have no part, a world that it is impossible for us to know through our senses."

But after the results of all my experiments, which confirm the ingenious views of Claude Bernard, it can no longer be affirmed that life is a principle or a mysterious directive force escaping the influence of natural phenomena.

Life is nothing more than the extremely complex physicochemical functioning of protoplasmic organisms produced by their incessant relations, their continual exchanges of elemental matter, and the different forms of energy.

IX. THE BIOLOGICAL IMPORTANCE OF LATENT LIFE.

This study of latent life not only brings us preciseness as to the nature of life and of death, but it touches also on the biological problems concerning the dissemination and conservation of life.

In fact, this peculiar property of latent life confers on all organisms that possess it the power to traverse time and space. It is to be noted that the seeds which preserve their germinative power the longest are almost always heavy ones which can not be transported by the wind, and which if buried must wait during a long time conditions favorable to their germination and growth. Most of these seeds belong to the families Leguminosæ, Nelumbonaceæ, Myrtaceæ, Malvaceæ, and Cistaceæ. The same remark applies to the eggs of certain crustaceans which are deposited in the mud of ditches, marshes, and streams which often run dry. Thus, Giard, in his researches on anhydrobiosis, informs us that the dried eggs of Apus survived for 12 years until the arrival of the water necessary for hatching.

Many bacteria profit by their state of latent life to await for years a time favorable for their multiplication. It is in this way that dangerous epidemics suddenly appear.

As Pasteur has shown, anthrax germs from a buried sheep brought to the surface of the earth by earthworms sooner or later make a pasture dangerous to the flocks. In the same way the wretched hovels in which people die of tuberculosis from generation to generation, notwithstanding ineffective disinfections and numerous removals of tenants, owe their danger to the presence of dried bacilli in the dust that is inhaled during sweeping.

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[1] Lodge, La vie et la matière. Alcan, Paris, 1907.

This persistence of vitality of cells may also be characteristic of tissues of the human body and may be advantageously utilized. This is what the splendid researches of Dr. Carrel are demonstrating to-day. This investigator, profiting by the experiments of Paul Bert, of which I have already spoken, has succeeded in preserving in a state of latent life certain tissues gathered aseptically from fresh corpses, such as fragments of skin, cornea, blood vessels, and bony tissues. These tissues protected from the air in sterilized vaseline at a temperature of 3° to 5° C. have preserved their vitality for 40 days, and consequently may be used for grafting. When some such method shall have been perfected it will render inestimable service to surgery.

Still other biological deductions result from the conservation of latent life, particularly when it is under the influence of low temperatures. For instance, germs arrested in their development may at this moment be subjected to the actions of complex causes which are determining their evolution. Borings made on continents covered with ice, such as the South Pole and the vicinity of the North Pole, where the temperature oscillates between 40° and 60° below zero, will perhaps permit us to gather seeds or old spores which have conserved their germinating power for many thousands of years under the action of the cold.

Arrhenius goes still further in his deductions. He thinks that latent life is sufficient to enable germs to traverse the icy void of interstellar space intact during an almost unlimited period. To demonstrate it, the Swedish scientist has formulated his ingenious theory of interastral panspermism. I have already had occasion elsewhere to explain and discuss this hypothesis.[1]

Unfortunately, worlds can not be sown with germs in latent life, propelled by light from one to the other, because the action of the stellar ultra-violet rays in the center of the solar systems and even in the atmosphere of planets is too harmful, but also because there would be needed a very improbable concurrence of extraordinary conditions. So it is necessary to seek other modes for the propagation of germs in infinity. In advance of their discovery, there results from my researches upon latent life, from the point of view of the future of life on the globe, a conclusion which, notwithstanding its great probability, will not fail to astonish us. This conclusion is that on the day when the sun shall be extinguished, when all the gases of our atmosphere shall have disappeared, as took place on the moon, when active life shall be destroyed, latent life will still be able to exist for a long time on the surface of the earth.

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[1] Paul Becquerel, La panspermie interastrale devant les faits: Revue Scientifique, Feb. 18, 1911, and C. R. Acad. des Sc., July 4, 1910.

Indeed, at that moment there will be found realized by nature the vacuum, dryness, and low temperature, the three conditions necessary for the conservation of germs which we have obtained simultaneously in our experiments. Upon that day, on this frozen, uninhabitable planet, wandering in the darkness of cosmic space, what will become of the stored seeds, and eggs, and spores? If the planet should be captured by a new solar system, will there be produced, under the action of new radiations, an atmosphere and a wakening of latent life, the beginning of a new evolution of beings? If this contingency is not fulfilled, and the planet is demolished by a shock or an explosion, will its débris, charged with germs, as Lord Kelvin believes, sow other worlds?

For my part, I do not believe so, because at the present time the study of meteorites does not justify this conjecture. And it is a pity, because latent life, which is a true Providence for the terrestrial conservation of beings, would have been the best means that nature could have employed to confer on certain animal and vegetable species a sort of celestial immortality.

THE EARLY INHABITANTS OF WESTERN ASIA.[1]

By Felix v. Luschan, M. D., Ph. D.,
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[With 12 plates.]

Standing on the "New Bridge" in Constantinople, near the Mosque of the Sultan Validé, I have more than once tried to count the languages and dialects spoken by the crowds pressing and pushing between Galata and Stamboul. Turkish and Greek are naturally the most frequently spoken, but one also easily distinguishes much Armenian, Arabic, Kurdish, and Persian. We hear the harsh voices of some Circassian soldiers, and learn from an Abkhasian friend that he does not understand their language and that "it might be" Lesghian. He also tells us that many of his Circassian friends serving in the same regiment are obliged to speak Turkish when they want to understand one another.

We then meet Albanians, Bulgarians, Roumanians, and are addressed in Serbo-Croatian by an old priest from Bosnia. You are sure to hear in less than five minutes five other modern European languages, English, French, German, Italian, and Russian, and then your ear is delighted by the melodious Spanish of some Spaniole Jews from Salonika, who still retain the idiom spoken in Spain when they were expelled from there more than 400 years ago, and have thus actually preserved the language spoken by Cervantes. And we hear other Jews on their pilgrimage from Russia and Poland to Jerusalem, speaking their curious Yiddish, a sort of German that no German could understand without making it a special study. Once on this bridge, I had to play the interpreter between a Hungarian Gypsy and some Aptals or other Gypsies from Anatolia, and an instant later I saw a Dinka eunuch sitting on the motor car of an imperial princess and making his selam to a group of equally dark and equally tall Bari or Shilluk.

Bilin and Nuer also are very commonly spoken by Stamboul eunuchs, and I was once told by one of my colored friends there that more than 1,000 female servants are living in metropolitan palaces, all coming from Bornu and speaking Kanuri. Another day, on the same bridge, I met some East Indians, speaking, as they told me,

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[1] The Huxley Memorial Lecture for 1911. Reprinted by permission from The Journal of the Royal Anthropological Institute of Great Britain and Ireland, vol. 41, 1911. July to December. London.

Hindi, Hindustani, and Gujerati, and trying in vain to come to an understanding with a large troop of African hajjis returning from Mecca, some of whom were Hausa, others from Zanzibar and the Swahîli coast, others from Wadai and Baghirmi. One may also meet on this bridge Mohammedans from China and from Indonesia, and, to complete this Babylonian confusion of languages, some day or other even a Papuan from Doreh or some other place in Dutch New Guinea may appear there on his hajj to Mecca.

Not less numerous than the languages are the types one meets in Constantinople or in any other of the larger towns in western Asia, and even within a linguistic group there is generally a most striking diversity of somatic qualities. There are Turks with fair and Turks with dark skin; Greeks with short and Greeks with long heads; Arabs with broad and low noses; and other Arabs with narrow and high noses; Kurds with blue and Kurds with black eyes; and the more one studies the ethnography of the Ottoman Empire the more one sees that "Turks" in reality means nothing else than Mohammedan subjects of the Padishah, that "Greeks" means people belonging to the Orthodox church, and that "Arabs" are people speaking Arabic—the somatic difference between a Bedouin from Arabia or Mesopotamia and an "Arab" farmer from near Beyrout is striking, and they have nothing in common except their language.

Also the study of the modern religions in western Asia is of no help to us in this labyrinth of types. There are Greeks who look like Mohammedans, and many Ansarîyeh or other ("Moslem") sectaries are not to be distinguished from Armenians. Religion, too, is here much more closely connected with late historical events than with races or nations, and is only too often of a merely accidental character.

Even the old historians do not help us. Their anthropological interests were generally trifling, and important statements like the note that the Armenians "*πολλὰ φρυγίζουσιν τῇ φωνῇ*," or that a tribe from the Solymian Mountains spoke Phœnician, are extremely rare in the old writers, who give us names like Lycians, Carians, Cilicians, Paphlagonians, Cappadocians, Lydians, and so on, but, generally, do not give us the slightest details as to their place in an anthropological system.

So we can well understand how, 50 years ago, G. Rosen, then perhaps the best authority on the nations of Asia Minor and Syria, could say that the anthropology of western Asia would "always remain a mystery."

Since then minute anthropometric researches and vast excavations have both thrown light on most of the problems connected with this "mystery," so that it may now be considered as practically solved.

My own way of proceeding was to eliminate one by one every national or racial element that could be traced as having come from outside, and then to study the remainder. It was my good fortune to begin archeological and anthropometric field work in Lycia as early as 1881, and since that time I have never ceased to collect all available data connected with the natural history of man in western Asia. So it is the work of 30 years of which I shall now try to give a short account, and this will be done best by beginning with the ostensible foreign elements and then describing the remaining tribes and groups.

A. DARK AFRICANS.

These are naturally by far the easiest to eliminate, and they have only in a very insignificant way contributed to the building up of the white communities in Asia Minor and in Syria, although they have been imported there from the earliest historical times down to our own days. Even now there are few houses of wealthy Mohammedans without dark servants, male or female, and without half-caste children of the most various tints. Nowhere, perhaps, with the exception only of Brazil, could miscegenation be better studied than in the large towns of the Levant. Domestic slavery is still flourishing there, and "black ivory" generally comes, as in the old times, from the Upper Nile, but also from Bornu. In the Turkish-speaking south of Asia Minor a dark African is generally called "Arab," in Syria, "Maghrebi" or "Habeshi." As far as I know, social inferiority is never connected with color; half-castes frequently intermarry with whites, but still there is no real negro permeation of the other natives, probably because that section of the offspring which reverts to negro qualities does not stand the climate.

B. CIRCASSIANS.

About a million of the Mohammedan inhabitants of the Caucasus immigrated into Asia Minor and Syria after the fall of Shamyl. The lot of these muhajir (refugees) was generally a melancholy one; the Ottoman Government did its best to give them land, but land without a master is rare also in Turkey, and in many places the result was a fight of all against all or a state of regular brigandage, often resulting in the final extinction of the Circassians. Where the land given to them was really masterless, it lay in unhealthy swamps and marshes, where malaria raged and carried them off at a terrible rate year by year. I know a place near Islahiyeh where more than 1,000 Circassian families were settled about 1880; now only 7 of them remain, and these in a wretched state of fever and disease. Only a very few of these Circassian colonies are really thriving, and probably most of these glorious sons of snowy mountains will in a few generations have paid with their lives for their fidelity to Islam.

Till now the Circassian blood has not seriously influenced that of their Turkish neighbors and probably never will. The colonists very seldom give their daughters to Turks or Arabs, and the "soft Circassian beauties" play a larger part in fiction than in actuality.

C. ALBANIANS.

The number of Arnauts or Albanians actually living in Asiatic Turkey is said to be about 100,000. Many of them serve in the army, some are high government officials, a few are even in the diplomatic service and famous for their unusual intelligence. Most of the "kavasses" of the foreign consuls and rich merchants are Arnauts, and so are nearly all the boy servants in the Turkish bath establishments. Most of the large "hans" (caravanserai) in the interior are also managed by Albanians.

It is easy to separate these Albanians from the great bulk of the other Islamic elements of the Ottoman Empire, because they are all proud of their nationality and stick to their native language. They intermarry rarely with aliens and are remarkably homogeneous as to their physical qualities. They are nearly all dark, tall, with large, extremely brachycephalic skulls, and high and very narrow noses. Somehow connected with the Dinaric race they have by long inbreeding and isolation in their nearly inaccessible mountains acquired their remarkable and quite peculiar type.

D. BULGARIANS.

The few thousand Bulgarians living in Asiatic Turkey are mostly confined to Constantinople and some towns on the north coast of Asia Minor. Their language and their garb permit us easily to isolate them, and they are so few in number that we may neglect their influence on the somatic qualities of their alien neighbors.

For the same cause also we may here omit the Roumanians and Serbs.

E. BOSNIANS.

Since 1879 probably not one Austrian Lloyd steamer has left Trieste for Constantinople without having on board some Mohammedans from Bosnia and Herzegovina desirous of escaping Christian rule. They settle by preference near Brussa, and will probably in some generations have a certain influence on the type of the Islamic inhabitants of the neighborhood. It may therefore be stated here that, though they are called "Turks" in Austria, they have no Turkish blood. They are descendants of the typical South-Slavonic population, which inhabited Bosnia and Herzegovina long before the battle of Kossovo-polye (1389) and were after the fall of the Servian Empire forced to turn Mohammedans. They do not even speak Turkish, but have preserved their old Serbo-Croatian language.

The very few Bosnians, mostly officers, that settled in Asiatic Turkey before the Austrian occupation of Bosnia may be omitted here.

F. FRANKS AND LEVANTINES.

Frenghi (Franconians or Franks) is the common name for the European Christians (and also for syphilis) all over the nearer Orient, and the descendants of European, generally French and Italian, and therefore Roman Catholic, families are called Levantines. They take only a minimum share in the building up of the oriental populations. In Marmaritza near Halikarnassos, where a British squadron had a winter station for many years, a very great proportion of the children are said to be flaxen-haired, and at Kynyk, the ancient Xanthos in Lycia, I met in 1881 a Mohammedan, quite fair, with light blue eyes, of rare intelligence, and with nearly a fanatical interest in geographical and archeological problems. He was born in 1841, a year after the second expedition of Sir Charles Fellows, at Xanthos. Near Sendjirli I know an Armenian woman who is very fair; her own people pretend that she is the daughter of an American. But all these are rare exceptions, of no general importance, and I feel sure that the modern admixture of European blood is in no way responsible for the great number of light-colored people also in the interior of Asia Minor and Syria.

That in Oriental towns with very hot summers the death rate of light-colored children in Frankish and Levantine families is essentially larger than that of dark-colored has been often asserted, and would naturally be of universal anthropological interest if proved by serious statistics. Personally I do not know of one single light-colored Levantine family in places infected with heavy malaria.

G. JEWS.

As the oriental Jews practically never mix with the other orientals, and so do not contribute in any way to the physical qualities of their oriental neighbors, they would be of no interest for this paper if we could not trace them back to very early times. But their racial position can only be investigated in connection with the old and oldest anthropology of Syria and Palestine. So for the moment we must here confine ourselves to the statement that there are several very distinct groups of oriental Jews.

By far the most numerous are now the Sephardim, speaking an early Spanish dialect, and descended chiefly from Jews expelled from Spain by the narrow-minded fanaticism of the fifteenth century. They have contributed not a little to the intellectual and economic development of the Ottoman Empire.

Of far less importance are the Ashkenazim, speaking "Yiddish," and descended from Jews emigrated from eastern Europe. The difference between these two groups was originally merely geographical and accidental, but now they are holding themselves rigidly apart, and I know of a small Ashkenazic community in southwestern Asia Minor that abstains from meat rather than eat of an animal killed by a Sephardic butcher. I could not learn if there were also differences in creed, but practically these two groups are like different sects, and in most places there is less intercourse between them than there is between Protestants and Catholics in the most backward villages of Central Europe.[1] This is perhaps of some importance in connection with the fact that both Ashkenazim and Sephardim are equally distinguished by a complete absence of uniform racial characteristics, just as it is with our Jewish friends in Europe.

The "enlightened public" of course knows better. Some Jews themselves state that they are "pure Semites, chosen and selected," and even in modern scientific papers one may still read of the complete "uniformity" of the Jewish type. But this uniformity only exists in the books and not in reality. There are Jews with light and with dark eyes, Jews with straight and with curly hair, Jews with high and narrow, and Jews with short and broad noses; their cephalic index oscillates between 65 and 98—as far as this index ever oscillates in the genus homo. Indeed, since my paper on the anthropological position of the Jews[2] there is, as far as I know, no serious anthropologist who still maintains the cranial uniformity of the Jews. It is also conceded that the great majority of the Jews is decidedly brachycephalic, whilst the typical Semites are essentially dolichocephalic. But even giving up the cranial uniformity, one still speaks of the marvelous tenacity, frequency, and distinctiveness of the Jewish type of face. Now this "Jewishness" is much more easily felt than defined, and Joseph Jacobs[3] (1885) was the first to try an exact definition. It is a certain and typical development of the nostrils (Jacobs's "nostrility") that is the best characteristic of what we generally call "Jewish."

Weissenberg,[4] wanting to prove a specific Jewishness of type, relates how he showed some hundred photographs of Russians and Russian Jews without distinguishing or peculiar dress, etc., to two friends, a Russian and a Jew; the first was correct in 50 per cent, the second in 70 per cent of his statements. I do not think this experiment very convincing; Weissenberg should have shown his friends photos of Greeks, Armenians, and Persians. The number of correct identifications would then have been certainly very much smaller, and it would have become evident that what Weissenberg takes to be "Jewishness" is nothing more than oriental, pure and simple. I shall refer to this statement toward the end of this paper, and meanwhile only want to advert to Table II, on page 571, showing in the thick line the cephalic indices of 1,222 Jews; 52 per cent of these were Sephardim, whom I measured at Smyrna, at Constantinople, at Makri, and in Rhodes; the rest were Ashkenazim measured by myself when I was one of the medical assistants in the Allgemeine Krankenhaus at Vienna, Austria.

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[1] R. Andrée, in his Volkskunde der Juden, quotes a passage in the Jewish Chronicle, 1878, where an Ashkenaz asks if "those Portuguese are real Jews, or only a sort of half-castes but distantly related to our glorious race?" A Portuguese answers him that "we are the Jews of the highest caste, as may be best evidenced by the fact that we have always refused to assimilate ourselves with the lower caste—the Tedeschi." So felt the Jews in London, and in 1864 the Sephardim of Bucharest bought a churchyard for themselves, to have nothing in common with the Ashkenazim, even after their death!

[2] "Die anthropologische Stellung der Juden," Correspondenzblatt der deutschen anthropol. Gesellschaft, 1892. Also in an Italian translation by Prof. Ugolini in Arch. per l' Antropologia e l' Etnologia, vol. 22, 1892.

[3] "On the racial characteristics of modern Jews," Journal Anthropol. Inst., 1885, vol. 15, p. 23 ss.

[4] Globus, Bd. 97, 1910, p. 329.

Besides these two large groups there are other Jews in Turkey and in Egypt, who have been there since the early times of the Diaspora and longer. But they are few in number and I had no opportunity to measure any of them.

H. GYPSIES, APTAL, ETC.

A small but highly interesting group is formed by the Gypsies and their kin. About 30,000 of them are said to infect Turkey with their disorder and inclination for theft and larceny. On the other side, they are cheerful company, men and women, not seldom with a certain beauty.[1] They make baskets and sieves; the men are mostly blacksmiths and shrewd horsedealers. They are never settled in houses, but wander with their goat-hair tents, in winter time on the plains, in summer high up in the mountains. I once met a small "village" of about 10 Gypsy tents as high up as 8,000 feet. Unhappily, nothing is known about their early migrations and history; they speak Turkish in Asia Minor, Arabic in Syria, and keep secret their own language with so much care that my various and repeated efforts to get at least a few phrases turned out a complete failure.[2]

In northern Syria I met a kind of Gypsies calling themselves "Aptal"; they lay a certain stress upon their *not* being Gypsies, but I could find no real difference either in their somatic qualities or in their ethnographic or social standing. Some of them often wander about like dervishes in groups of four or five, and with a large red or green banner; others are jugglers and conjurers and play tricks with serpents.

Gypsies never, or hardly ever, mix with other tribes in Syria or Asia Minor. They naturally pretend to be Mohammedans and have Islamic names, but they are always treated with a certain contempt or disesteem. Mohammedans hardly ever curse; but one of their rare abusive phrases is *tchingene*=gypsy.

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[1] Cf. some types I published in Petersen and von Luschan, Reisen in Lykien Milyas und Kibyratis, Wien, C. Gerold's Sohn, 1889.

[2] Henry Minor Huxley (American Anthropologist, vol. 4, 1902, p. 49) examined at Jerusalem a few gypsies of Syria that spoke Arabic, "but among themselves fluently Gypsy. Many of their words have exactly the same forms as are found in Hindu Gypsy words." I do not know if this statement is confirmed by other explorers.

Till now we have been treating of a few isolated groups that are very easily separated from the bulk of the tribes of western Asia. We now come to some nomadic tribes, who also form quite distinct groups: Turkomans, Yuruks, and Kurds.

I. TURKOMANS.

Real Turkomans, coming from west Turkestan, are rather rare in Asia Minor, and I never met any in Syria. They travel in quite small groups, one or two families only, and are to be distinguished even at a great distance, as they are the only tribe in Asia Minor which has the real camel with two humps, all the others having the dromedary. I once met a family of such Turkomans, near Old Limyra in eastern Lycia, that had come "from near Samarkand." They had been away from home four years and wanted to go as far as Constantinople; in five or six years more they thought—*inshallah*—to reach their home.

Some of these Turkomans have very oblique eyes; all have small roundish heads and are of low stature, seldom exceeding 160 centimeters. They do not mix with the native inhabitants.

J. YURUKS.

Another nomadic tribe found in Asia Minor in far greater numbers than the Turkomans, is formed by the Yuruks. The word means "wanderer," and many misunderstandings are due to this ambiguity, as all sorts of "wanderers" have been described as Yuruks, just as settlers in South Africa sometimes speak of "Bushmen," not meaning the real Pygmy-Bushmen, but dark and tall Kafirs living "in the bush."

I wrote upon the real Yuruks in the Z. f. E. 1886, vol. 18, Verh. p. 167 ss., and may here refer to this paper and to the plates in Reisen in Lykien, etc., quoted here (p. 559, note 1).

They are remarkable for the artificial deformation of their heads and their generally long skulls. Their real home is not known. They speak Turkish, and up to the present no trace has been found of their original language. I once suggested that they might be in some distant way related with the Gypsies, with whom at least some of them have a decided and striking somatic resemblance; it then seemed to me possible that their high moral standard, their serious and decent ways, and their assiduity in work—their wives are famous carpet makers—might be due to Islam. But this was a mere suggestion, and it might well be that their resemblance to the Gypsies is only quite accidental. I hope that others may be more successful and find legends and traditions, remains of the old language, or other material that would permit us to trace the Yuruks back to their real home.

Meanwhile a sort of jealousy between them and the settled Mohammedans excludes intermarriage almost without exception.

K. KURDS.

Kurdistan, the land of the Kurds, is a vast mountainous territory, nearly twice as large as Greece, in the southeast of the Armenian mountains. Its frontiers are undefined and uncertain, changing with the scattering or gathering of a floating mass of chiefly nomadic inhabitants.[1] The greater northwestern part is under Ottoman, the southeastern under Persian, control. We know of no political unity of the Kurds, and, as far as we can trace back their history, they were always forming many different tribes (ashirets) under independent chiefs, whose strength was only broken in the last century, in Turkey not without the aid of H. v. Moltke, then a young Prussian officer.

The Kardouchoi and Gordyaeans of the old historians are most probably the direct ancestors of the modern Kurds, but we do not know when these tribes first set their foot upon the soil of their present home. The Assyrian annals and careful excavations on the upper Euphrates and Tigris will probably, at some future time, shed light upon this question.

Meanwhile it is important to state two facts: The Kurds speak an Aryan language, and they have long heads and generally blue eyes and fair hair.

I have studied three groups of Kurds, 115 men near Karakush, 26 men on the Nimrud-Dagh, and 80 men from near Sendjirli—all adults. In the Karakush series 71 men were xanthochroic, on the Nimrud-Dagh 15, and in Sendjirli 31, this being 62, 58, and 39 per cent, respectively, and for the whole number of 221 adult men, 53 per cent. The cephalic index oscillated, in the case of the 115 Karakush Kurds, between 713 and 785, with the Nimrud-Dagh men between 723 and 783, and in Sendjirli between 744 and 809, the arithmetic mean being 749, 752, and 769. Two good types are here reproduced. (Pl. 1.)

The Kurds from Karakush and from the Nimrud-Dagh live nearly isolated. I found only one or two small Armenian merchants with them. The Kurds from Sendjirli stay near "Turkish" and Armenian villages, and it is known that they sometimes steal and marry Armenian wives, and not seldom they intermarry with "Turks" so it is probable that the Kurds from Sendjirli are less typical than those from Karakush and Nimrud-Dagh.[2] I saw many other Kurds on the plain between Kyrykhan and Marash, whom I could not measure, but who seemed to be in absolute conformity with the Kurds I had measured. So I may state that the western Kurds are dolichocephalic with an average index of 75, and with more than 50 per cent of fair adults—the heads becoming shorter and larger, and the hair and eyes darker, with the increasing admixture of "Turkish" or Armenian blood.

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[1] The best statistics on Kurds are due to Mark Sykes, Trans. Roy. Anthrop. Inst., vol. 37, 1908, p. 451 ss.

[2] The greater number of xanthochroic men on the Nimrud-Dagh and in Karakush compared with their smaller number in Sendjirli may be due partly to the splendid, cool climate of these mountain villages.

So much for the western Kurds. We are up to the present very ignorant as to the somatic qualities of the eastern Kurds. I have myself only seen a very few Kurds from Persia, but the general impression of some of my scientific friends is that the eastern Kurds show a much higher percentage of darker and round-headed men than the western.

The language of the Kurds is split into many dialects; yet two main groups are to be distinguished, a western and an eastern. Both are related to modern Persian and are typically Aryan. So, if we ask for the real native country of the Kurds, there can only be one answer. It must be the same as that of our own race, of the race of Northern Europe. It is not my concern here in this paper to treat of the Aryan problem, and I feel myself utterly free from any Pan-Germanic aspirations in the style of Gobineau and Chamberlain, but still I believe in an old "blue-eyed, fair-haired, long-headed race as in an impregnable complex and not a synthetic accident."[1]

And can it be mere accident that a few miles north of the actual frontier of modern Kurdish language there is Boghaz-Köi, the old metropolis of the Hittite Empire, where Hugo Winckler in 1908 found tablets with two political treaties of King Šubbiluliuma with Mattiuaza, son of Tušratta, King of Mitanni, and in both these treaties Aryan divinities, Mithra, Varuna, Indra, and Našatya, are invoked, together with Hittite divinities, as witnesses and protectors.

And in the same inscriptions, which date from about 1380 B. C., the King of Mitanni and his people are called Harri, just as nine centuries later in the Achæmenidian inscriptions Xerxes and Darius call themselves Har-ri-ya, "Aryans of Aryan stock."

So the Kurds are the descendants of Aryan Invaders and have maintained their type and their language for more than 3,300 years.

L. TAḪTADJI.

In Lycia there are about 1,000 families, or 5,000 souls, of a people calling themselves Taḫtadji or boardcutters—"sawyers." This is indeed their principal occupation. In Western Lycia their Mohammedan neighbors call them Allevi, a name that is perhaps connected with the word Ali-Ullahî or Layard's Ali-Illahiya,[1] meaning people that worship Ali. I treated at large of this curious sect in 1889,[2] so that I can be brief here.

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[1] Verbally quoted from a paper of R. N. Salaman, "Heredity and the Jew," in Journal of Genetics, vol. 1, p. 274. The author of this very interesting paper holds the opposite opinion and believes in a "synthetic accident."

They live high up in the mountains, generally in tents covered with felt, sometimes in round [!] houses, and keep rigidly apart from all the other inhabitants of Lycia. They speak Turkish, are originally regarded as Mohammedans, and have also Mohammedan names, but they have no inner connection with the creed of Mohammet. They believe in metempsychosis and in good and bad demons. Hares and turkeys are considered as unclean, and the peacock as a sort of incarnation of the devil.

Their somatic qualities are remarkably homogeneous; they have a tawny white skin, much hair on the face, straight hair, dark brown eyes, a narrow, generally aquiline nose, and a very short and high head. The cephalic index varies only from 82 to 91 with a maximum frequency of 86. The mean length-height index is 781, the mean facial index, 876. A typical skull of a Taḥtadji is figured here (pl. 11).

M. BEKTASH.

Whilst the Taḥtadji live high up in the mountains of Lycia, a similar sect, the Bektash, dwells in the Lycian towns, principally in Elmaly. Their creed has never been exactly studied, and they are very anxious to keep it secret. Like the Taḥtadji they affect a certain affinity with the real Moslems, but they never intermarry with them.

I published the measurements of 40 adult male Bektash in my paper on the Taḥtadji[2] and quote from it here, that the cephalic index oscillates only between 84 and 89, and the auricular height-index between 74 and 83, with two maxima at 75 and 82. The facial index has a very distinct maximum at 86.

N. ANSARÎYEH.

Exactly corresponding to the Taḥtadji and the Bektash in southwestern Asia Minor are the Ansarîyeh = Nussairîyeh in northern Syria.

In some places, as in Antiochia (ad Orontem), they are called "Fellaḥ"—from their principal occupation—but have no connection with the Fellaḥ of Egypt. All that is known about their creed is exactly parallel to our knowledge of the Taḥtadji, and the same tales of nocturnal orgies, "jus primæ noctis," and "spiritistic" meetings are told of both groups.

Many Ansarîyeh have also in their general appearance a striking likeness to some Lycian Taḥtadji. I measured 15 adult men.

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[1] A. H. Layard, Nineveh, vol. 1, p. 296 ss.

[2] Petersen and von Luschan, Reisen in Lykien, etc., Wien, C. Gerold's Sohn. Partly reprinted in Archiv. f. Anthr., vol. 19, 1890.

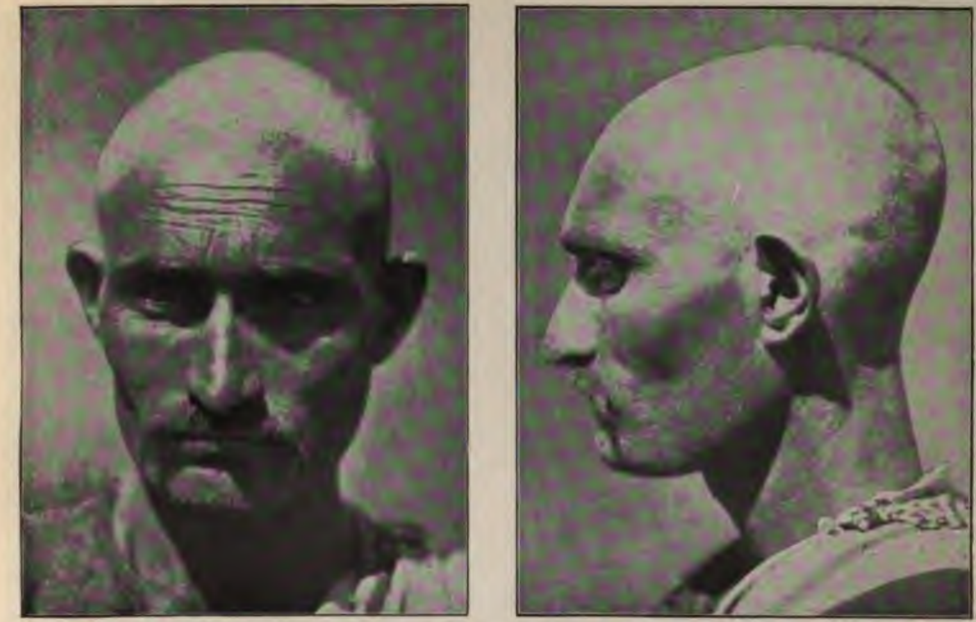
Their cranial index varies from 80 to 94, with a maximum at 85. (Compare plate 2.)

O. KYZYLBASH.

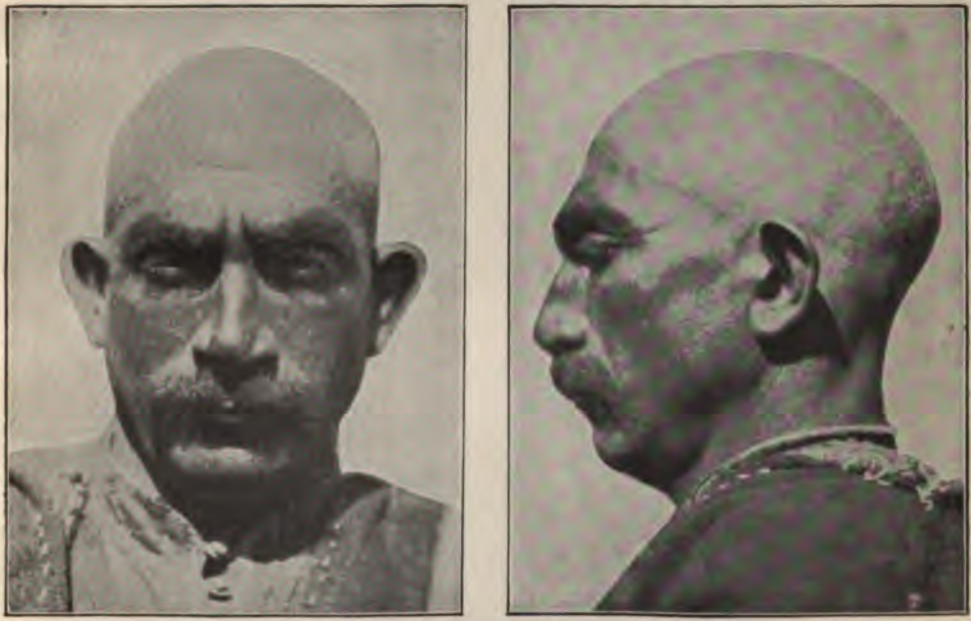
In Upper Mesopotamia and in small groups reaching in the west as far as the High Taurus, near Marash, there is a curious people, living in the midst of Arabs and Kurds, which calls itself "Kyzylbash," a word that means "redhead" in literal translation. But there are not more red-haired individuals among them than among their neighbors, and their head dress is not more red than that of any other Oriental group. So the word can not mean what it seems to mean, and had its origin perhaps in quite another word in another language; in the same way that popular etymology made "ridicule" from "reticula" or, in German, "mutter-seelenallein" from "moi tout seul." Perhaps linguists will one day find out the real origin and meaning of Kyzylbash.

In some places in western Kurdistan people that are exactly like the Kyzylbash are called "Yezidi," and protest that they have nothing at all to do with the Kyzylbash; in other places, so I was told one day at Kiakhta, on the Böilam River and again near Diarbekr, that Yezidi and Kyzylbash were two words for the same thing, the one being Arabic, the other Turkish. I do not know if this is correct, but, as far as I could ascertain, the creed and the social condition of both groups are fairly identical. Sir A. H. Layard's classic report on this sect is so complete and exhaustive that I have nothing more to add than a few words on the physical characteristics. They are strangely homogeneous. I was able to measure 189 adult men; only three of them had grayish eyes, all the rest had dark brown eyes, dark hair, and tawny "white" skin. Their cranial index varies only from 83 to 92, with a well-defined maximum at 86. The index of the auricular height varies from 75 to 83, and the facial index from 80 to 90, with a pronounced maximum at 86. I could measure only a few noses; they were all very high and leptorrhine, and so seemed, with few exceptions, all the rest.

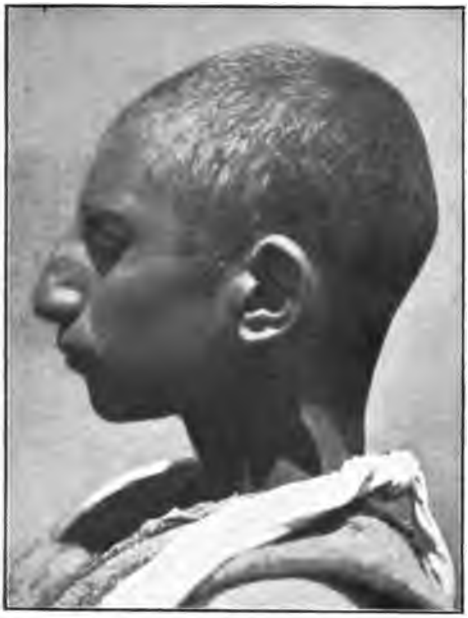
So these Kyzylbash are excessively short and broad-headed in the midst of dolichocephalic Kurds and Arabs; their nose, too, is much narrower than that of their neighbors. On the other hand, the Kyzylbash [and the Yezidi] correspond absolutely with the Taḥtadji, the Bektash, and the Ansarîyeh, so that we find a small minority of groups possessing a similar creed and a remarkable uniformity of type, scattered over a vast part of western Asia. I see no other way to account for this fact than to assume that the members of all these sects are the remains of an old homogeneous population, which have preserved their religion and have therefore refrained from intermarriage with strangers and so preserved their old physical characteristics.



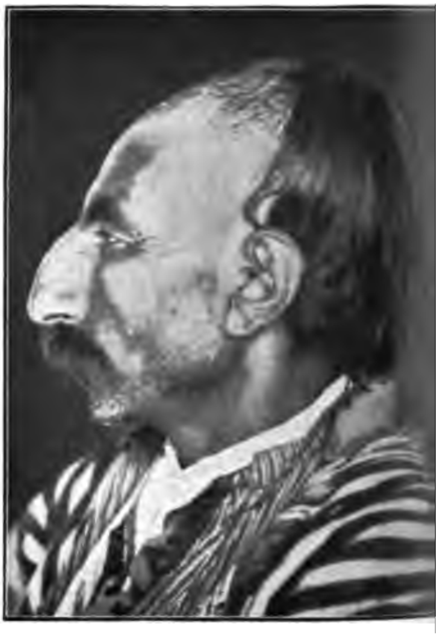
IBO, KURD, NIMRUD-DAGH, 1883.



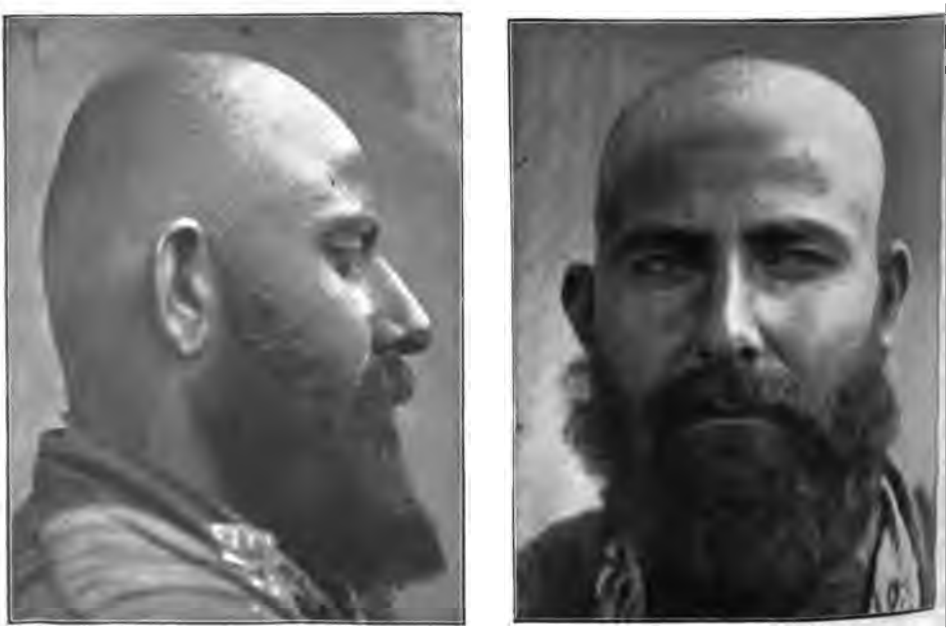
BAKO, KURD, NIMRUD-DAGH, 1883.



SULO, "KURD," ATYPICAL, KIAKHTA.



ARMENIAN, AINTÀB.



HABIB, ANSARÎYEH, SCANDEROON.

Two other sects that are now to be mentioned, the Druses and the Maronites, show in the same way how religious seclusion tends to preserve old physical types.

P. DRUSES.

In the south of Beyrout a great part of the Lebanon and Antilibanos country is inhabited by about 150,000 Druses, who down to our days are to a certain extent independent of the Ottoman Government and enjoy a good many privileges.

Their secret creed has been studied best by S. de Sacy in 1838,[1] and contains, mixed with Jewish, Christian, and Mohammedan elements, a great many pantheistic conceptions, together with curious ideas on metempsychosis and the repeated incarnation of God, and with remains of the old Oriental worship of Nature. They speak Arabic and pass officially as "Mohammedans," having Islamic names, but they have no inner connection with the religion of Mohammet.

Max v. Oppenheim[2] believes the Druses to be the descendants of "Arabs," immigrated about A. D. 800.

This hypothesis probably conforms to local tradition, but is in direct contradiction to the general impression we get from Druses and from Arabs, and from the result of anthropometric researches. I measured 59 adult male Druses, and not one single man fell, as regards his cephalic index, within the range of the real Arab.

The Druses are all hyper-brachycephalic, with an index oscillating, like that of the Bektash, between 84 and 89 only, with one single exception, an old mischievous and half idiotic pensioner, who pretended to have once been first keeper of the Imperial Plate in Constantinople, and to be a real incarnation of Ali. His index was 76 without a suspicion of synostotic sutures; but he had gray eyes, and fell in many other respects so fully out of the line of the homogeneous rest of my Druses, that it seems safe to drop him entirely.

The index of the auricular height ranges from 74 to 84 and the facial index from 79 to 92, with a distinct maximum of 86, with 14 men in 58.

Q. MARONITES.

The northern neighbors of the Druses are the Maronites, Christians, generally said to be the descendants of a Monophysite sect, separated from the common Christian Church after the Council of Chalcedon in A. D. 451. Now, this council is certainly of the very greatest importance for ecclesiastical history, as it caused the schism between the Oriental world and the Occidental: the Greek, the Armenian, and the Coptic Church separated from the Roman, because the simple understanding and the sound common sense of the Orientals preferred to accept only one nature in Jesus Christ. But this theological dispute gave the name to the Maronites, for they chose a monk, John Maro, to be their bishop after they separated from Rome, but their physical qualities are much older than their religious schism. Indeed, partly through their isolation in the mountains, partly through their not intermarrying with their Mohammedan or Druse neighbors, the Maronites of to-day have preserved an old type in an almost marvelous purity. In no other Oriental group is there a greater number of men with extreme height of the skull and excessive flattening of the occipital region than among the Maronites. They are the best specimens of what C. Toldt[1] calls "planoccipital" formation, and very often their occiput is so steep that one is again and again inclined to think of artificial deformation. Indeed I took great care to make sure of this point and examined nearly a hundred babies in their cradles, to ascertain whether or not a particular way of laying the child's head on a cushion might perhaps influence the form of the occiput. No such possibility was found, and we are constrained to regard the extreme "planoccipital" formation of the Maronites (and their relations) as a natural character. Cf. the two types here (pl. 3.)

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[1] Exposé de la religion des Druses, vol. 2, Paris, 1838.

[2] Vom Mittelmeer zum Persischen Golf, Berlin, D. Reimer, 1899, vol. 1, p. iii ss.

I have measured 20 adult males, mostly from Baalbek and from Tarabolus. Their cephalic index ranged from 79 to 91 with an arithmetic mean of 86. The average facial index was 89, the irregular indices running from 75 to 94, with four cases of 87. All were dark.

Having thus treated of a series of smaller groups, we can now proceed to the five great groups of western Asia—Persians, Arabs, Turks, Greeks, and Armenians.

R. PERSIANS.

Notwithstanding some recent researches, our knowledge of the anthropology of Persia is rather scanty. In a land inhabited by about 10,000,000, not more than 20 or 30 men have been regularly measured, and not one skull has been studied.

Apart from Kurds, Arabs, and Armenians, each numbering from 200,000 to 300,000 souls, and smaller groups of Nestorians, Lurs, Gypsies, etc., there are two large ethnical groups in Persia, the Shiite and settled Tajik and the Sunnite and essentially nomadic Ihlat. The latter are Turkomans and so is the actual Dynasty of the Kajar; the Ihlat, being the energetic and vigorous element, are the real masters of the land and of the Tajik, the descendants of the old Persians and Medes. But long-continued intermarriage has produced a great many mixed types. Thus the Kajars have sometimes the high aquiline noses quite foreign to real Turkomans.

The old type seems to be preserved in the Parsi, the descendants of Persians who emigrated to India after the battle of Nahauband

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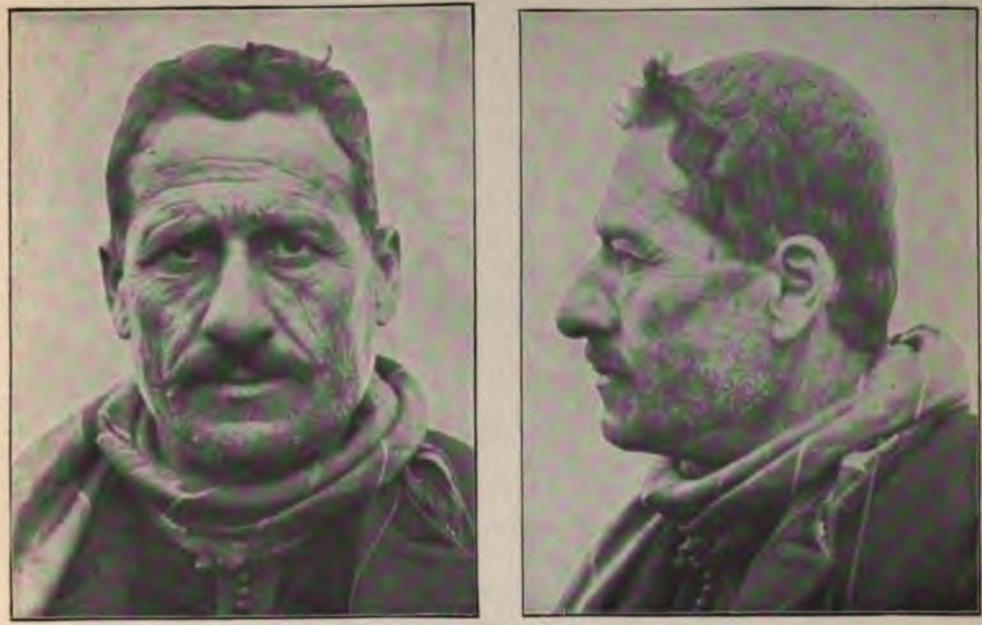
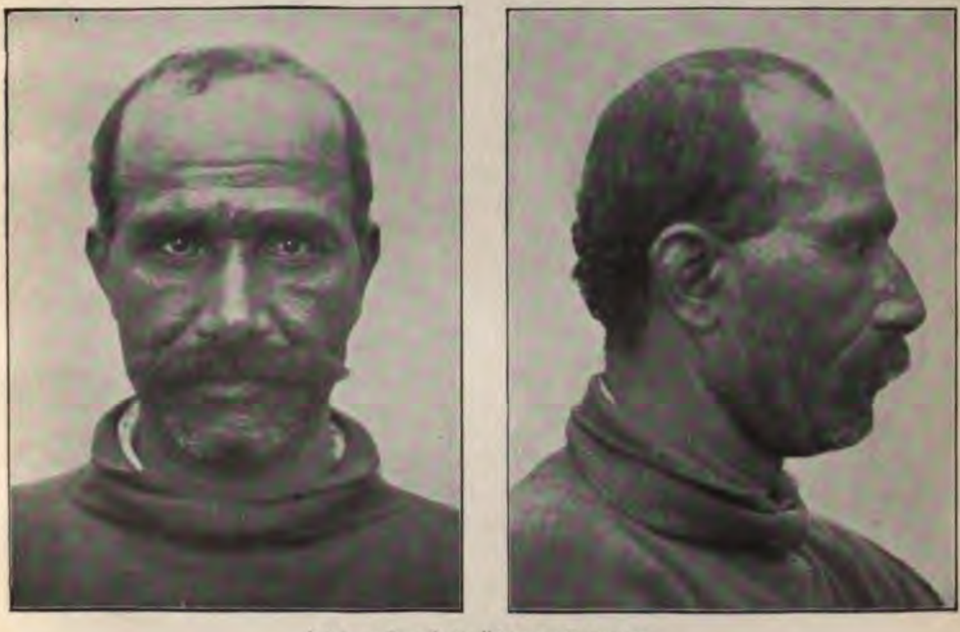
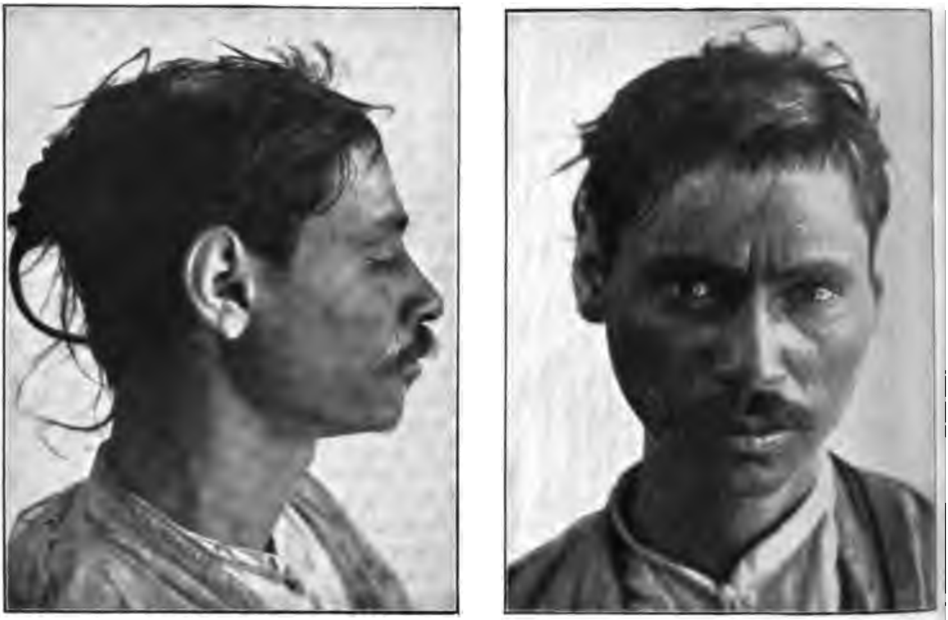
[1] "Untersuchungen über die Brachycephalie der Alpenländischen Bevölkerung," in *Mitteilungen der Wiener anthropol. Gesell.*, vol. 40, 1910, p. 69 ss. and p. 197 ss.



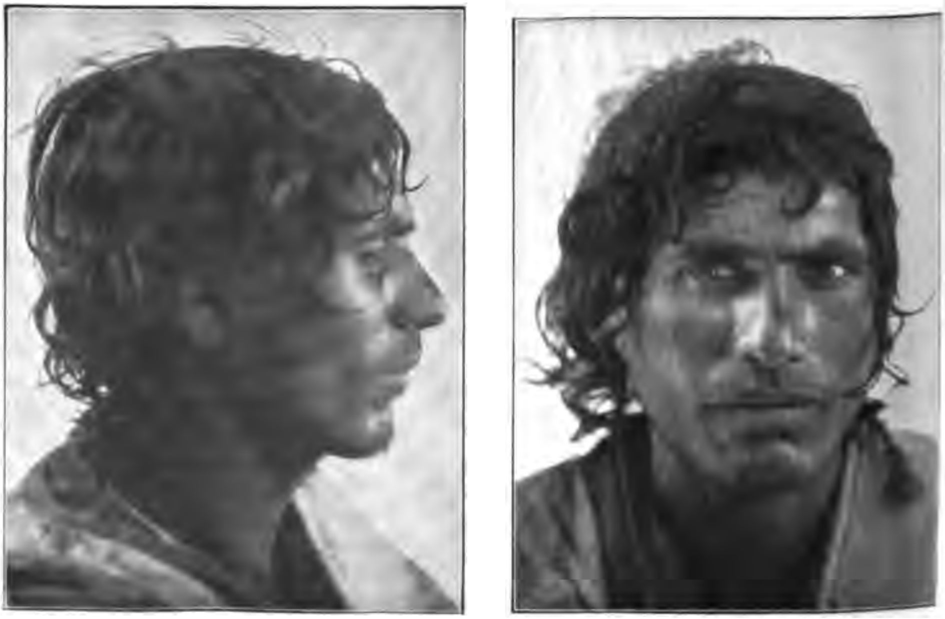
NEDSHIB HURI, "ARAB," SHUAFAT, LEBANON.



IBRAHIM IBN SAÏD, "ARAB," BEYROUT.



ANNESEH—BEDOUIN FROM NEAR BAGHDAD.



ANNESEH—BEDOUIN FROM NEAR MOSSOUL.

(A. D. 640), of much purer form than among any true Persians. They are all short headed and dark.

My own measurements are confined to 15 adult men, Persians of the Diaspora, diplomats, consuls, and tobacconists, whom I occasionally met in Constantinople, Smyrna, Rhodes, and Adalia. They were all very dark. Their cephalic indices run 73, 74, 74, 80, 81, 86, 86, 87, 87, 87, 88, 88, 89, 89, 90. So there is a large majority of brachycephals. I do not lay stress on the three dolichocephalic men, because a great number of Persians whom I saw, without being able to measure, seemed to be brachycephalic. Anyhow it is not impossible that in reality a certain number of Persians—I am very far from saying one-fifth of them—have long skulls. I never saw Persians with light hair and blue eyes, but I am told that in some "noble" families fair types are not very rare.

We know nothing of the physical characteristics of the Achæmenides, who called themselves "Aryans of Aryan stock" and who brought an Aryan language to Persia; it is possible that they were fair and dolichocephalic, like the ancestors of the modern Kurds, but they were certainly few in number, and it would therefore be astonishing if their physical characteristics should have persisted among a large section of the actual Persians. Still we must reckon with the possibility that an early "Aryan" invasion was not quite without influence also on the somatic qualities of modern Persians. Meanwhile much serious scientific work must still be done in investigating the anthropology of Persia ere we can replace mere conjecture by actual certainty.

S. ARABS.

In dealing with the peoples of western Asia, in no case is it more important to keep language and race rigidly apart than when treating of the Arabic-speaking people. Friedrich Müller called all the various elements in Arabia, Palestine, Syria, and Mesopotamia "Arabs," merely because they spoke Arabic. Nothing could be more erroneous. The material and mental culture of these tribes and their somatic qualities are widely distinct, and the extent of the Arabic language is infinitely larger than the extent of an Arabic racial element.

But peninsular Arabia is the least-known land in the world, and large regions of it are even now absolute "terræ incognitæ," so great caution is necessary in forming conclusions, from the measurements of a few dozens of men, concerning the anthropology of a land more than five times as great as France.

My own measurements are confined to 38 Annezeh-Bedouins, whom I met in 1883 in Aleppo; 18 other Bedawy, generally Shammar, camel drivers between Mosul and Alexandretta; 20 Mohammedan "Arabs" living in the town Hamah, the site of the first Hittite inscriptions published; and 15 other Mohammedans from Syrian towns. Two groups, unfortunately very small, consist of 6 priests from Gesyra, whom I met in Aleppo, and 5 men from Hail, in Arabia, whom I was able to measure in Constantinople—in all 102 adult men, 61 of them real Bedawy and 41 settled in towns.[1]

The cephalic indices of these "Arabs" ran thus:

	Number measured.	Cephalic index.
Bedawy:		
Annezeh	38	68 to 78
Other Bedawy	18	71 to 81
Men from Hail	5	70 to 74
Settled in towns:		
"Arabs" from Hamah	20	85 to 89
Other Mohammedans from Syrian towns	15	76 to 89
Priests from Gesyra	6	83 to 86

Remarkably parallel with the cephalic index is the form of the nose in both these groups. The Bedawy as a rule have short and fairly broad, the other "Arabs" have, with few exceptions, high and narrow noses, often of an aquiline form.

What we generally call a "Jewish type" is found very seldom among real Bedawy and very often among the "Arabs" in the towns, but it would be difficult to reduce this statement to a statistical form, as the conception of "Jewishness" is too uncertain and precarious. Two typical Bedouins are figured here. (Pl. 4.)

We shall later on try to understand the historical connection between these two types, the Bedawy and the other "Arabs." For the moment, we must restrict ourselves to having shown the marked difference that separates them.

T. TURKS.

It is customary in most European languages to call the Mohammedan subjects of the Padishah "Turks." But the word should never be used in this sense without inverted commas; it is more than ambiguous and easily leads to serious misunderstandings.

A Turkoman tribe, the Othmanli, commenced from 1289 to conquer a great part of what is now the Ottoman Empire. A good many of the former inhabitants were then forced to speak Turkish and to turn Mohammedans. It is easy to understand that the descendants of the conquerors and of the conquered renegades intermarried freely, and, as the number of the conquering troops was naturally very much smaller than that of the original population, the great bulk of the 10 or 15, or perhaps more, millions of so-called "Turks" has now the physical qualities, not of the conquering Othmanli, but of the old pre-Othmanic inhabitants.

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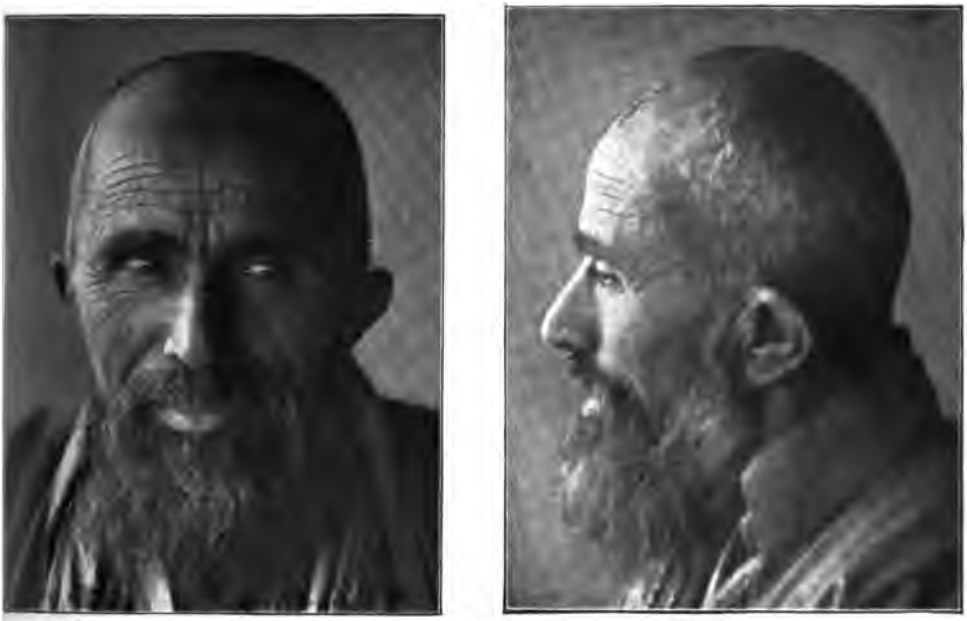
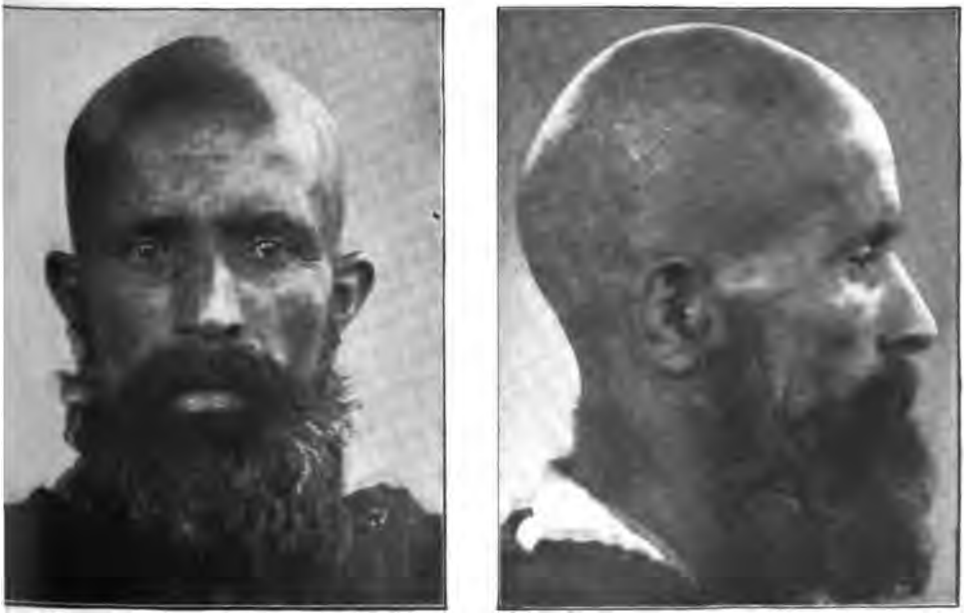
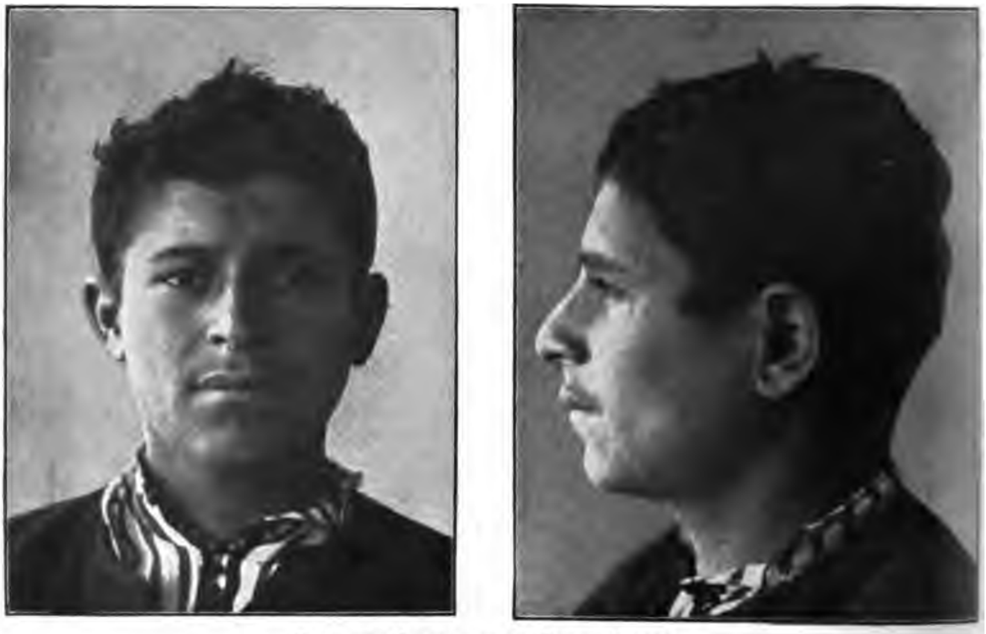
[1] I have measured 7 more "Arabs," but I omit their figures in this statement, because they were of mixed blood or in some way or other pathological.



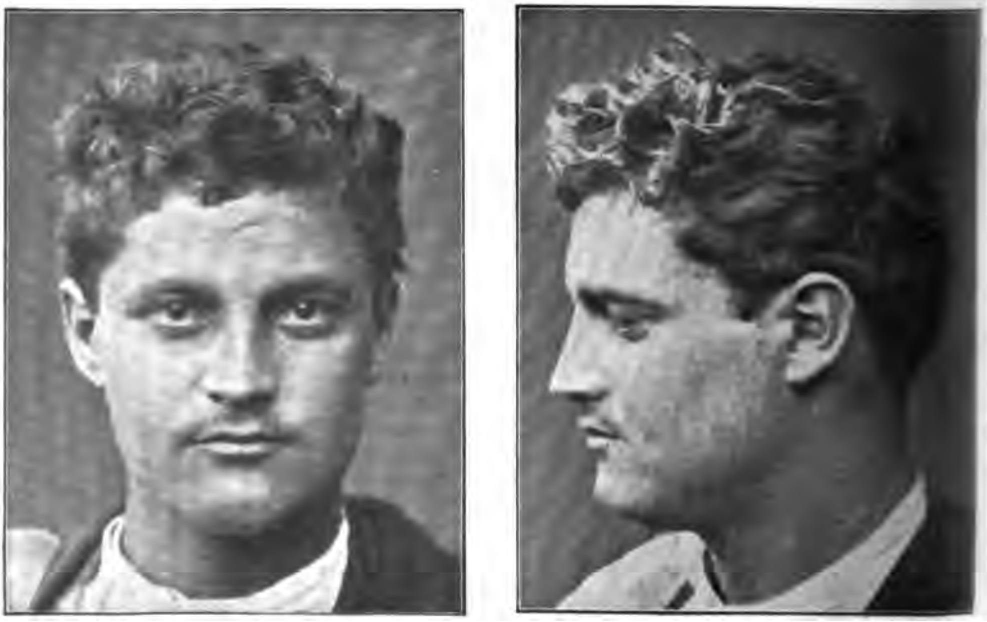
Hadschi Suleiman, Mohammedan, Girmeh (*ΚΡΗΜΝΑ*).



Ali Tshaush, Mohammedan, Aghlasan (*ΣΕΛΓΗ*).



GEORGIOS KONSTANTINOU, GREEK, LEVISSI.



GEORGIOS GLINIS, GREEK, TINOS.

So the anthropology of Turkey is, like that of Hungary, a typical example showing how language, religion, nationality, and race are quite distinct conceptions, and it is interesting to see how they are again and again confounded by the general public and by the press.

In my paper on the Taḥtadji [1] I gave the indices of 187 "Turks" (Turkish-speaking Mohammedans) from Lycia, and was able to show that in the mountain villages, and in some swampy marshes not easy of access, people were generally short headed, and in the towns and on the coast long headed. Since then I have measured 569 more "Turks" from southern Asia Minor and northern Syria, so that I can now publish the cephalic indices of 756 adult men; they run from 69 to 96; if we count the indices 77 to 81 as mesaticephalic, 172 of these 756 men would be dolichocephalic, 151 mesaticephalic, and 433 brachycephalic, with a very pronounced maximum of 77 and 83 men respectively at indices 85 and 86.

These numbers speak for themselves, but it is perhaps useful to study first the corresponding figures for the two large remaining groups, the Greeks and the Armenians, and then to compare the results. Two very different types of "Turks" are figured here. (Pl. 5.)

U. GREEKS.

What has been said of the "Turks" is valid too in absolutely the same way for the "Greeks" of Anatolia and Syria. Some of them are certainly the direct descendants of old Ionians, Dorians, or Æolians, but the greater part are descended from other groups which spoke Greek and had accepted the orthodox religion.

I must here pass over the interesting problem of the Dorian and Ionian wanderings [2] and must restrict myself to some measurements taken on a series of 179 adult men calling themselves Greek and belonging to the orthodox church. I published this series in 1890, in my paper on the Taḥtadji, and reprint here a graphic table showing the frequency of the cephalic indices. It is very striking to see how the curve shows a maximum of 22 men with an index of 75, and a second maximum of 18 men with an index of 88.

Seventy-nine out of the 179 men are dolicho-, 84 are brachy-, and only 16 are mesaticephalic. If we reckon the arithmetic mean for the whole series, we get an average index of about 80, closely conforming to Weisbach's 95 skulls of Asiatic and European Greeks with an average index of 81.2, and with the series of Klon Stephanos,[3] who found 80.8 for the Greeks in Europe and 80.7 for the Asiatic Greeks.

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[1] Op cit., p. 563, note 2.

[2] My own private idea is that, contrary to the theory of Curtius, the Ionians came from Europe and the Dorians from Asia, but I shall treat of this subject in another paper.

[3] Article on Greece in Dict. encyclop. des sciences med., Paris, 1884.

It is easily understood how dangerous and mystifying such an average index may be, if the material is composed of individuals from at least two different groups, as it manifestly is.

I am in possession of 93 skulls from a modern Greek cemetery in Adalia; they show about the same distribution of indices.

Long before the rediscovery of Mendel and his laws I tried to study the heredity of the cephalic index in the Greek families of Adalia. Here, in the old capital of Pamphylia, there is a large Greek colony, and as I had by good chance been able to give medical help to some of the influential members, I was permitted to measure parents, children and other relations in 67 families. The results were striking. I published a short abstract of them in 1889, in the Reisen in Lykien, and in 1890 in my paper on the Tahtadji.

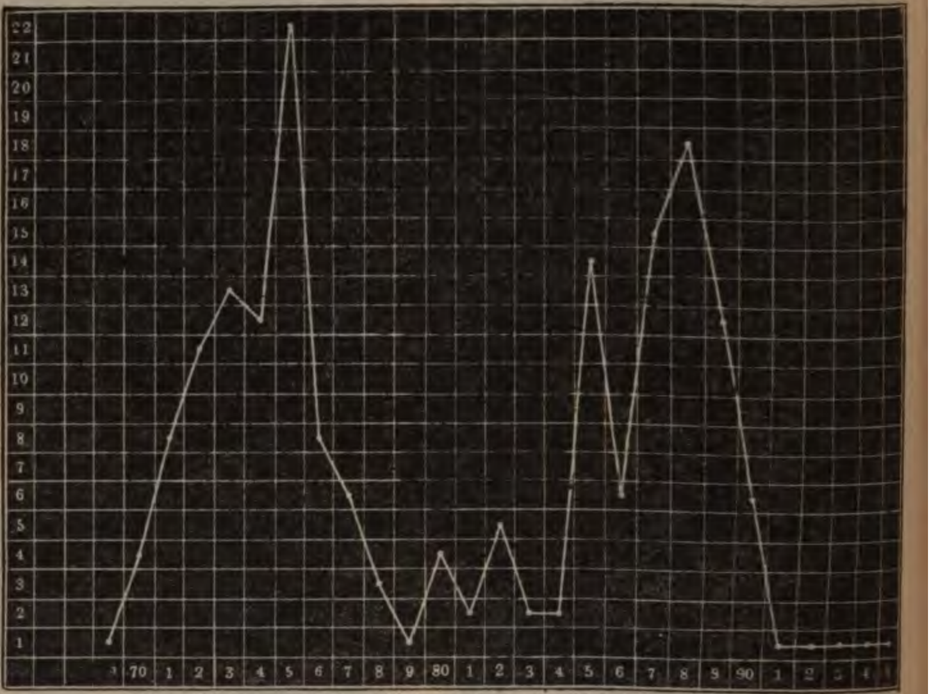

TABLE I.—Frequency of cephalic indices in a series of 179 adult male Greeks.

There was a family A; the father had an index of 87, the mother of 73; of the two sons, the elder had an index of 70, the younger 87. In another family, B, the brother of the dead father had an index of 70, the mother 86, a son 82, a daughter 75. In a third family, C, both parents were brachycephalic, with indices of 85 and 86. Of their five children, only the youngest daughter was short headed, with an index of 86, and four elder brothers had long heads with 72, 73, 75, and 73, respectively; 74 was the index of a brother of the mother.

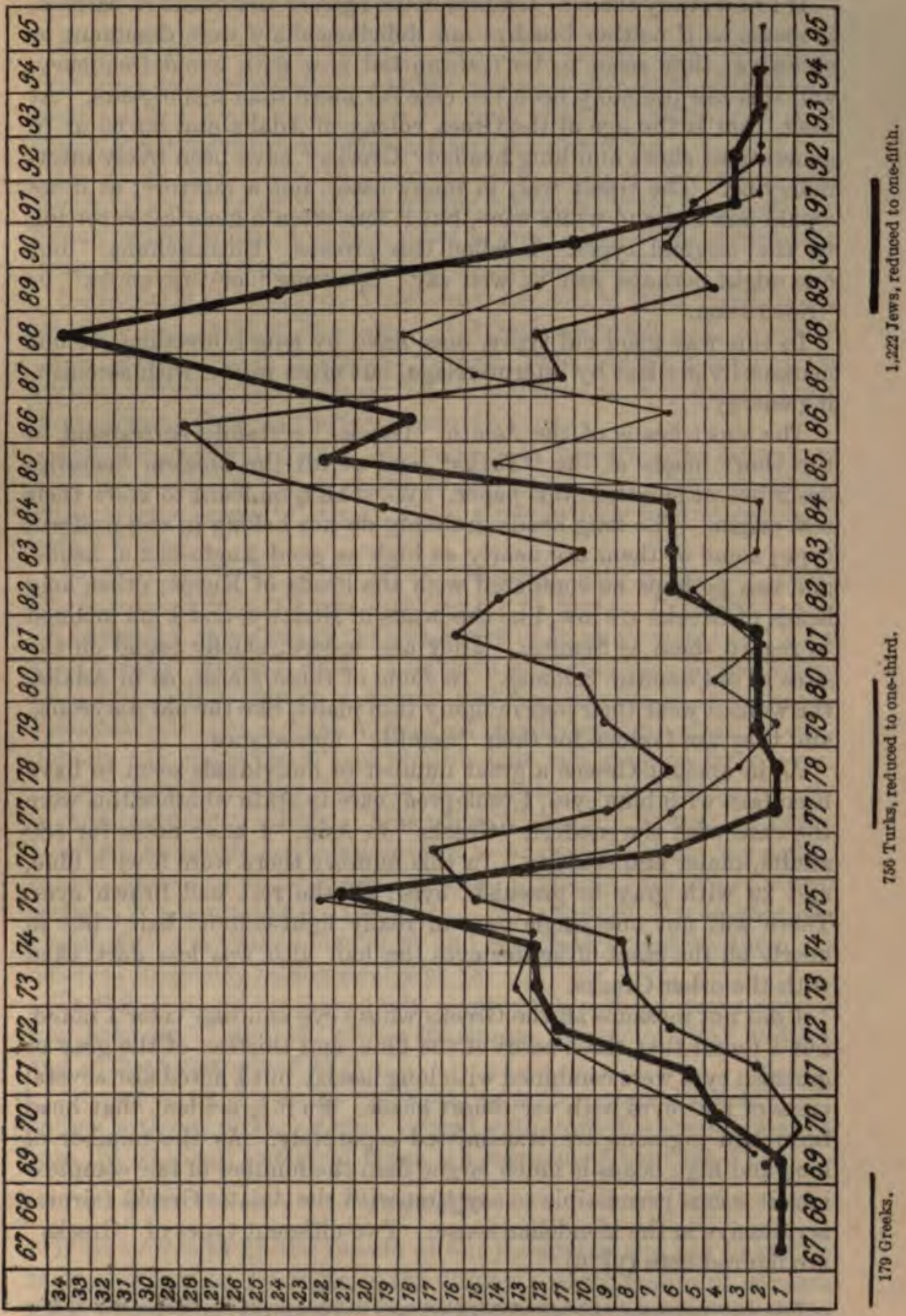

TABLE II.—Frequency of cephalic indices with Greeks, Turks, and Jews.

If I now study these 67 families in the light of Mendelian researches, it seems as if neither brachy- nor dolichocephaly were dominant or recessive; they seem to be transmitted now with equal frequency, and this has probably been the case for more than 2,000 years. At least, that is the age of the Greek colony of Adalia and for 60 or 70 generations short and long headed "Greeks" have been freely intermarrying. The result was, in many cases, not a mixture, as if we would mix red and white wine, but it was often a manifest reversion to the original types. I called this process "Entmischung," but one might perhaps just as well say "Spaltung" or "reversion" or "restitution."

In this way good old types, once fixed by long inbreeding, do not necessarily get lost by intermarriage, but often return with astonishing energy.

The short heads of the Asiatic "Greeks" certainly correspond to the short heads of the "Turks" and of all the Moslem Sectaries described at length in this paper. We shall soon learn to know their real origin. The long heads probably do not belong to one uniform type; some of them are nearly as high as good Anglo-Saxon heads, and can perhaps be compared with the heads of Kurds; other long heads of Greeks are low, like the heads of Bedawy, and I am inclined to regard them as Semitic. They are, indeed, chiefly found on the sites of old Semitic colonies. In some of these places, as in Adalia, the women wear their hair in many thin plaits, like the old Assyrians, and they are famous for their "Semitic" appearance.

As in ancient Greece a great number of individuals seem to have been fair, with blue eyes, I took great care to state whether this were the case with the modern "Greeks" in Asia. I have notes for 580 adults, males and females. In this number there were 8 with blue, and 29 with gray or greenish, eyes; all the rest had brown eyes. There was not one single case of really light-colored hair,[1] but in nearly all the cases of lighter eyes the hair also was less dark than with the other Greeks.

I did not measure all the Greeks whose eye and hair color I noted, but I found that three cases of the blue, and thirteen of the gray or greenish eyes were combined with long heads; but I noted also several cases of blue eyes with very short heads. So it is evident that head form and pigment are transmitted separately. As the number of long and high heads is much larger than the number of fair complexions it seems permissible to say that with the Asiatic Greeks fairness is recessive in the Mendelian sense. Two different types of "Greeks" are figured here (pl. 6).

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[1] With the exception of the young men at Symi, who are all flaxen haired. In summer they dive for sponges, and their hair is bleached by the combined effects of sun and salt water.

V. ARMENIANS.

Whilst "Turks" and "Greeks" have been proved to be composed of at least two quite distinct somatic elements, the third of the three great ethnic groups, which form the bulk of the inhabitants of Asia Minor, the Armenians, is comparatively homogeneous.

Of course they also have incorporated in themselves various alien elements, and I know Armenians from southern Persia who look like Biloch or Dravidians, but as a rule the great mass of the Armenians forms not only a religious, but also a somatic unity.

Particularly in northern Syria there are places where Armenians resemble one another like eggs. Religious seclusion and, in many cases, life in remote mountain villages, have both contributed to prevent intermarriage with strangers, and thus we may assume from the beginning that they represent an old type.

More frequently than any other group in western Asia they show the "planoccipital" form of the profile curve, great brachycephaly with extreme height of the skull and a particularly narrow and high nose (Cf. pl. 7).

They are generally dark; yet of 110 adult men, whom my friend Dr. Assadur Altounyan examined for me in Aleppo, 8 had blue, and 6 "greenish," eyes, and in my own series of 26 adult men 1 had light gray, another greenish, eyes. I have no good statistics on the Armenians from the Provinces of Erivan and Nahitshevan in the Russian Transcaucasia, but a great number of the Armenians, whom I occasionally saw from there, had reddish hair and gray or green eyes. I do not know with what elements they may be mixed, and think it safe to omit them here entirely. Also a few "Catholic" Armenians whom I met at Antiochia (ad Orontem) are to be excepted from my series, as they have a more prominent occiput; probably they are of mixed origin. If I omit these "Catholics," my series of true Armenians begins with a cephalic index of 83 and ends with one of 96, the maximum of frequency falling clearly at 88.

To this extreme brachycephaly corresponds a facial index oscillating between 77 and 96, with a maximum frequency of 87 and 88, and with an average of 87.5.

A series of 26 Armenian skulls begins with a cranial index of 81, ending with one of 91. A very typical skull from this series is figured here (pl. 11). and two good types are reproduced here (pl. 7).

SUMMARY.

If we now sum up the results of our researches and try to review them in regard to the origin of the different ethnic groups of western Asia, we need not linger over the Negroes, the Circassians, the Albanians, the Bulgarians, the Bosnians, the Franks, and the Levantines.

Their origin lies outside the scope of this paper. The same is true of the Gypsies and their kin, but it must be stated that perhaps one of the nomadic tribes in Asia Minor, the Yuruks, is in some way or other related with them.

Of far greater importance are the Kurds. From the great frequency of fair individuals among them, it is evident that their home must be in the north, and it is probable from their Aryan language that they are in some way connected with the Mitanni, who had Aryan divinities about 1280 B. C.

I am well aware that at present there is no real proof or decisive evidence for this statement, but, by way of a working hypothesis, I might be allowed to suggest that the Kurds, the Amorites of the Bible, the Mitanni of the Boghaz-köi tablets and the Tamehu of the old Egyptian texts are, if not identical, at least somehow related to one another.[1] About 1500 B. C., or earlier, there seems to have begun a migration of northern men to Asia Minor, Syria, Persia, Egypt, and India. Indeed, we can now connect even Further India with the Mitanni of Central Asia Minor. On the tablets of Boghaz-köi the king of Mitanni not only calls himself and his people "ḥarri," but he speaks of his noblemen as "mari," and Hugo Winckler and F. C. Andreas [2] remind us of the word "marya" for "young man" or "hero" in the Vedic texts. So we find the same Aryan nobles in Mitanni about 1280 B. C., and very much later also in India.

If really, as it seems, the old texts state that the Amorites and the Tamehu were fair, we should thus get a historic explanation of the great number of xanthochroic people we find down to our time everywhere in Asia Minor and in Syria, and among the modern Jews.

Resuming now the thread of this paper, we have a great number of different "Moslem" Sectaries spread over a vast part of western Asia under different names, as Taḥtadji, Allevi, Ali-Ullahîya, Ansarîyeh, Fellaḥ, Kyzylbash, Yezidi, and Bektash, speaking the different languages of their orthodox neighbors, Turkish, Arabic, and Kurdish, but still absolutely homogeneous as to their somatic characteristics. And to this selfsame group belong also the Druses and the Maronites. They also have the enormously high and short "planoccipital" heads and the narrow and high noses we find with the Sectaries.

Now this same hypsicephalic element with the high aquiline noses, which forms the entire stock of all these Sectaries, we find again in Persia, and in a high percentage among the Turks and the Greeks, and in a still higher among the Armenians—everywhere under circum-

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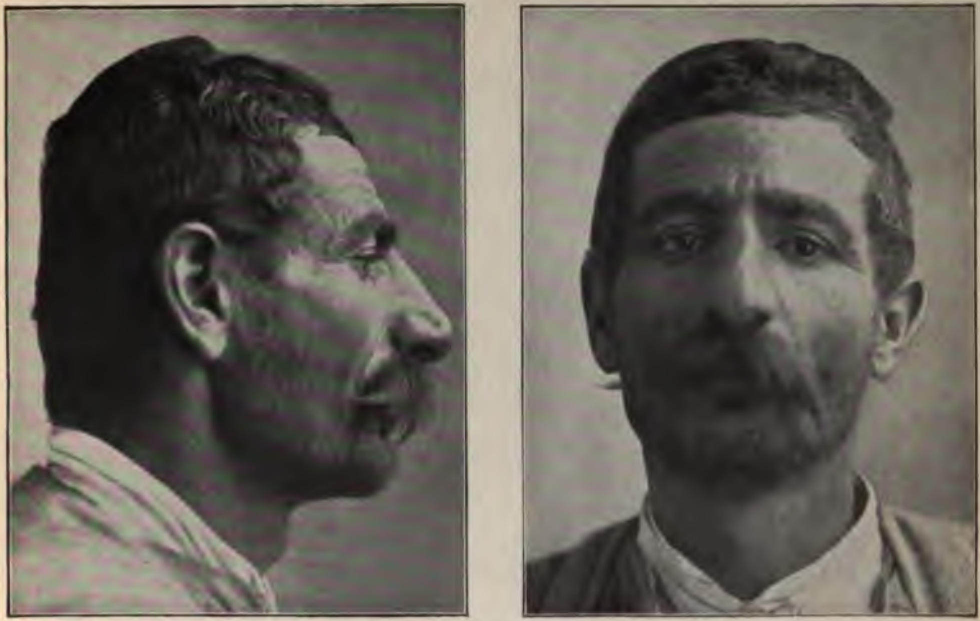
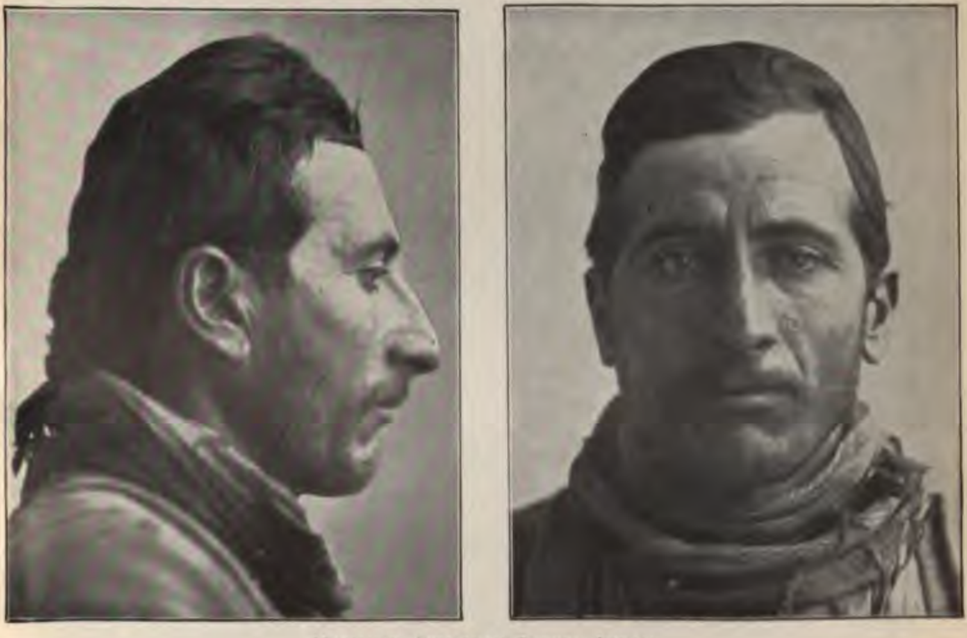
[1] The latest migration of a European tribe to western Asia is that of the Galatians. Passing through Roumania, where the town of Galatz (Galati in Roumanian) has conserved their name, they crossed the Hellespont about 280 B.C. Angora and Gordion were their principal towns, and it is not impossible that the latter name, and then also that of the Gordyaeans and of the Kurds, is linguistically connected with that of the Galatians, who might have had earlier precursors.

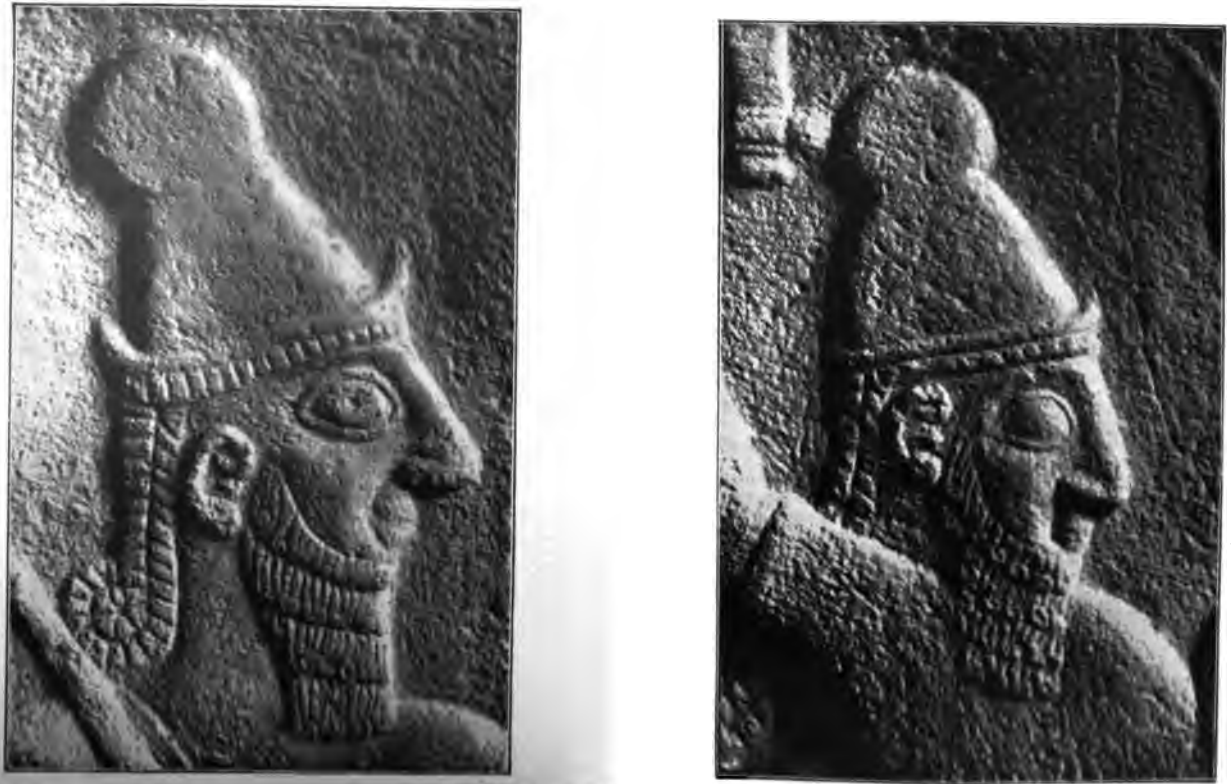
[2] Orientalistische Literaturzeitung, 1910, p. 289 ss. Cf. also Ed. Meyer, "Das erste Auftreten der Arier *in der Geschichte*," in Sitzungsberichte Berliner Akad. der Wissenschaften, 1908, i.



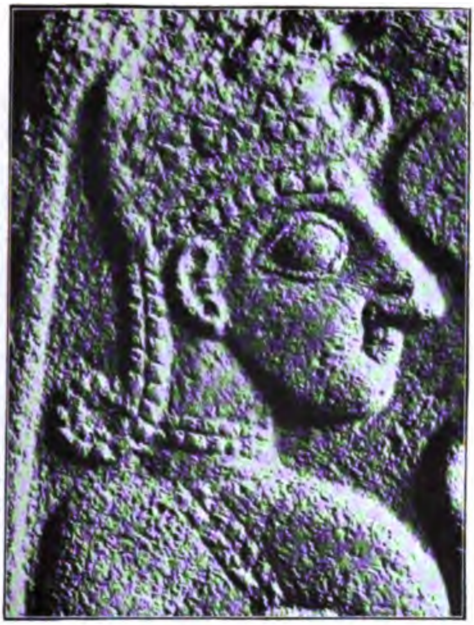
STEPAN, ARMENIAN, KESSAB, DJEBEL AKRAH.



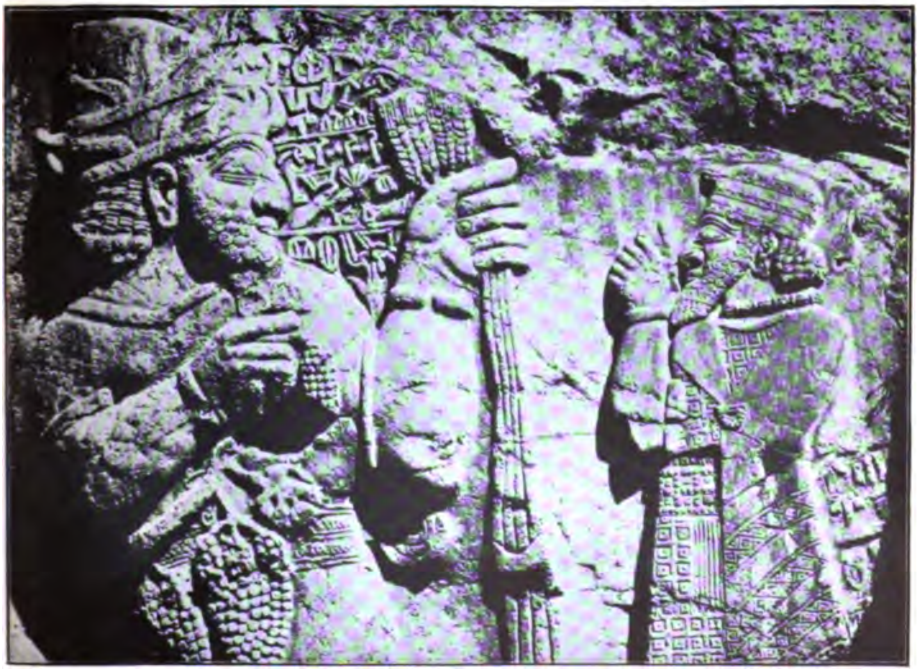
KYRIAKOS, ARMENIAN, DJEBEL AKRAH.



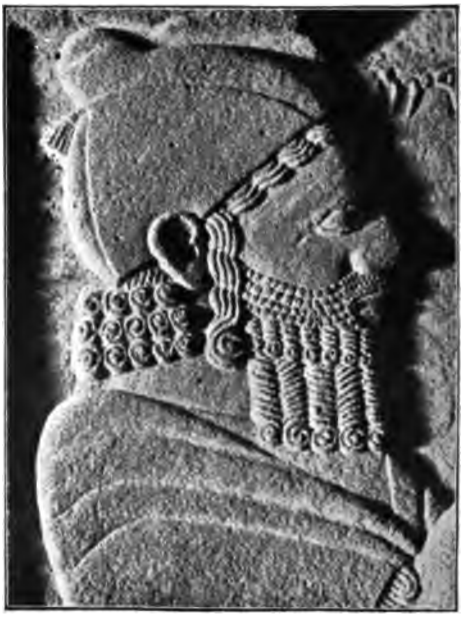
HITTITE DIVINITIES, SENDJIRLI, SYRIA.

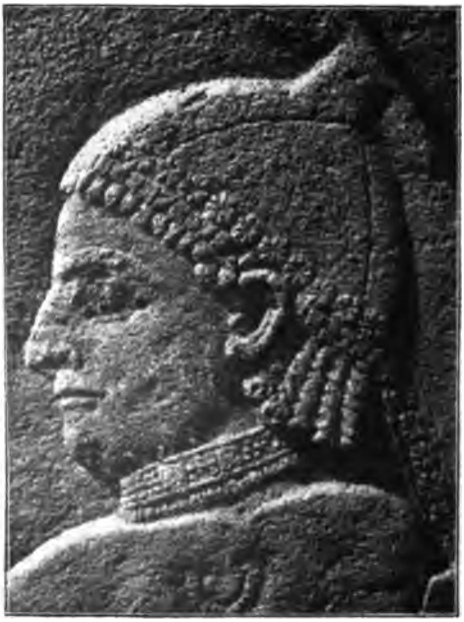


HITTITE DIVINITY, SENDJIRLI, SYRIA.



HITTITE GOD AND KING, IBRIZ (WITH HITTITE INSCRIPT





KING BARREKUB OF ŠAMÂL, AND QUEEN, ABOUT 730 B. C.
(WITH SEMITIC INSCRIPTION).

stances that would make it appear to be old and aboriginal, whilst the dolichocephals seem to represent later immigrations.

This theory, based entirely on anthropometric research, is confirmed by historic considerations and by the results of modern excavations. We now know that about 1280 B. C., when Khattusil made his peace with Rameses II, there existed a large empire, not much smaller than Germany, reaching from the Ægæan Sea to Mesopotamia and from Kadesh on the Orontes to the Black Sea. We do not know at present if this Hittite Empire ever had a really homogeneous population, but we have a good many Hittite reliefs, and all these, without one single exception, show us the high and short heads or the characteristic noses of our modern brachycephalic groups.

When I first upheld in 1892, in my paper on the anthropological position of the Jews, the homogeneous character of these groups, I called them "Armenoids." But there can be no doubt that they are all descended from tribes belonging to the great Hittite Empire. So it is the type of the Hittites that has been preserved in all these groups for more than 3,000 years, and this is certainly a Jewish type, and corresponds with the old Jewish ideal of beauty as we read in the Song of Songs, vii, 4: "Thine eyes are as the pools in Heshbon, by the gate of Bath-rabbim, thy nose is like the tower of Lebanon, which looketh toward Damascus."

But this Jewish type is not Semitic and is rarely found among the only real Semites, the Bedawy. The Hittite inscriptions have not yet been read, but our orientalists are unanimous in assuming that there is not the slightest doubt that the Hittite language was not Semitic. These non-Semitic aborigines had their own language, their own writing, and their own religion. Semitic influence is completely absent in the earlier times and is perceptible only later on at different times in the different territories—first in Babylonia, then in Palestine, where Abraham is the *ἥρως ἐπώνυμος* of a Semitic invasion, and still later in Northern Syria. Here my own excavations[1] in Sendjirli, the old Šamâl, have brought to light a Semitic inscription of King Kalamu, son of Yadi, from about 850 B. C., invoking Baal Semed, Baal Haman, and Rekubêl. Another inscription of King Panamu from about 800 B. C., on a statue of Hadad, praises Hadad himself and four other Semitic divinities, El, Rešef, Rekubêl, and Šemeš.

As Tešup, the great chief-god of the Hittites, is not mentioned in any of the Semitic inscriptions of Sendjirli, we may suppose that about 900 B. C., or earlier, independent of the Assyrian conquests, Semitic invaders brought with them their language, their alphabet, their writing, and their religion, to northern Syria, but we know nothing of their number, and we are not able from historical data to form an exact opinion as to how far these invaders could influence the somatic characters of the old Hittite population.

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[1] Ausgrabungen in Sendschirli, parts 1–4. Berlin, Georg Reimer, 1893–1911.

I give here (pl. 10) the portraits of a later king of Šamål, Barrekub, from about 730 B. C., and of his queen. The king has certainly not a Hittite profile, and he might well himself be of Semitic origin, but probably a great number of his subjects had preserved the old Hittite characteristics, and even the queen herself looks as she were not quite without Hittite blood.[1]

For the present population of northern Syria, as well as of all western Asia, our anthropometric tables show evidence that this old type is still extant in a high percentage among the actual inhabitants.

Only as to the primordial home of the Hittites, or however else we may term all these hypsi- and brachycephalic people with the high and narrow nose, is there some difficulty. The "Alpine race" of central Europe is certainly somehow related to or connected with them and a priori it is not easy to determine if the Hittites came from central Europe or if the "Alpine race" came from western Asia. I do not know if the first possibility has many champions left now. If so, they might certainly lay stress on the fact that the modern Armenians and the modern Persians, both typical "Hittites," are now speaking Aryan languages, but we know how often ethnic groups change their language entirely without losing their somatic type, and we can in this special case well imagine that early precursors of the xanthochroic Kurds and their relations may have brought their Aryan language to the old Armenians and Persians without being able to impress their somatic type upon them.

We should not forget, too, that Europe is only a small peninsular annexe to Asia, and that there are infinitely more typical "Hittites" in western Asia than there are in Europe. It seems surer, therefore, to locate the cradle of the Hittites in Asia, where we find extreme brachycephals as far to the east as Burma and Siam and the Malay Archipelago.

We could then also understand how the essential somatic difference between the Hittites and the other brachycephalic Asiatics—their high and narrow nose—originated as a merely accidental mutation and was then locally fixed, either by a certain tendency of taste and fashion or by long, perhaps millennial, inbreeding. The "Hittite nose" has finally become a *dominant* characteristic in the Mendelian sense, and we see it, not only in the actual geographical province of the Alpine race, but often enough also here in England. Certainly, similar noses may originate everywhere, quite independently of the

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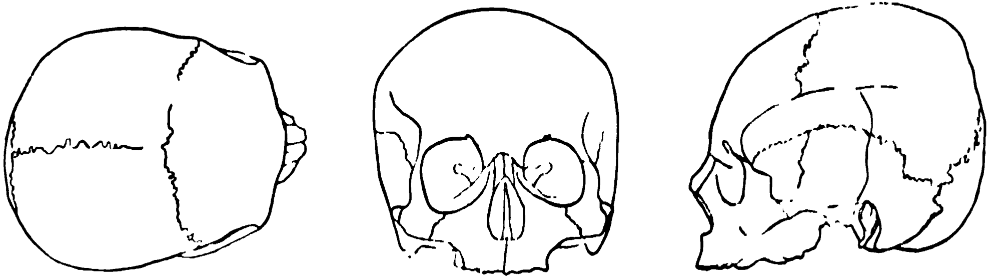
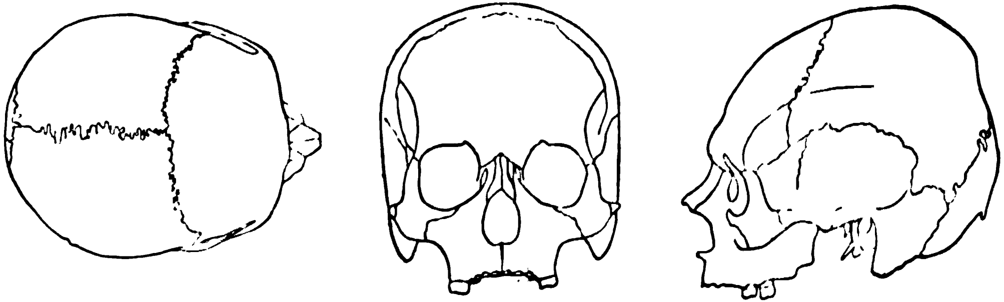
[1] Typical portraits of Hittite divinities, excavated at Sendjirli, are here reproduced on pls. 8 and 9, and the rock sculpture of Ibriz (cf. here pl. 9) shows a Hittite god and king, both with extreme "Jewishness." On Egyptian monuments Hittites are always figured with a profile like the modern Armenian (pl. 2). The young "Kurd" Sulo (pl. 2), also belongs to this group; his mother, whose type he has inherited, is an Armenian woman.

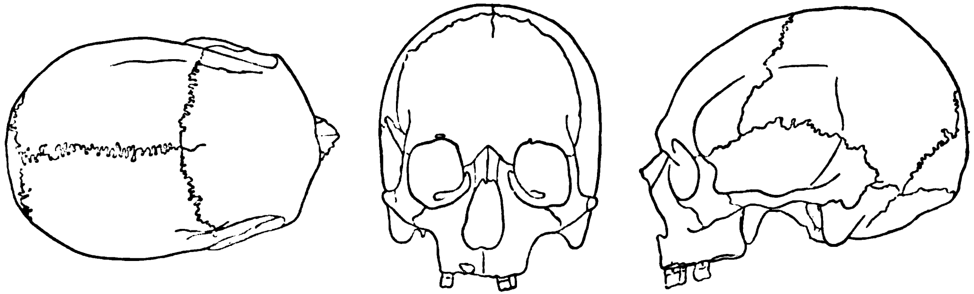
PLATE 11.



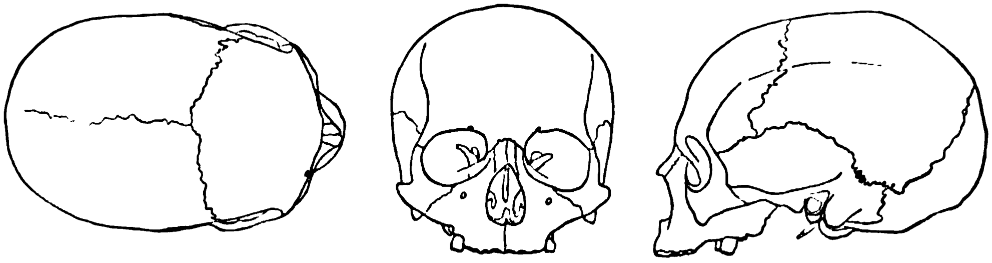
SKULL OF TAḤTADJI FROM NEAR OLD KADYANDA, LYCIA.



SKULL OF TYPICAL ARMENIAN.



SKULL OF BEDOUIN FROM NEAR PALMYRA.



SKULL OF MODERN "GREEK," ADALIA.

Hittites, by mere mutation, but it seems safer to explain by atavism and by Asiatic or Alpine origin noses like those of the late Cardinal Newman, Ralph Waldo Emerson, or Charles Kingsley.

So, to sum up, we see how all western Asia was originally inhabited by a homogeneous, melanochroic race, with extreme hypsi-brachycephaly and with a "Hittite" nose. About 4000 B. C. began a Semitic invasion from the southeast, probably from Arabia, by people looking like modern Bedawy. Two thousand years later commenced a second invasion, this time from the northwest, by xanthochroous and long-headed tribes like the modern Kurds, half savage, and in some way or other, perhaps, connected with the historic Harri, Amorites, Tamehu, and Galatians.

The modern "Turks," Greeks, and Jews are, all three, equally composed of these three elements, the Hittite, the Semitic, and the xanthochroous Nordic. Not so the Armenians and the Persians. They, and still more the Druses, Maronites, and the smaller sectarian groups of Syria and Asia Minor, represent the old Hittite element, and are little, or not at all, influenced by the somatic characters of alien invaders.

Combinations of philology with anthropology have in former times, especially through Friedrich Müller and his school, often led to serious mistakes. One spoke of Aryan races instead of people with Aryan languages, and one went so far as to speak of Aryan skulls and of Aryan eyes, so that Max Müller formally protested against the intrusion of linguistics into ethnology, stating that one might just as well speak of a brachycephalic grammar as of an Aryan skull.

Still there is a solidarity between the historical sciences and natural history, and in proof of this solidarity I have ventured—in the spirit and in honor of Thomas Henry Huxley—to give argument and evidence.

EXCAVATIONS AT ABYDOS.[1]

By EDOUARD NAVILLE.[2]

[With 3 plates.]

I. THE TOMB OF OSIRIS.

There was a city in Egypt called by the Greeks Abydos. This is an example of a popular etymology or rather popular transcription. Its Egyptian name was "About," which through resemblance of sound recalled the distant well-known Grecian city of Abydos on the Hellespont, made famous by the passage of the army of Xerxes, and led to calling the Egyptian city by that name. It played no part in the political world, but became famous chiefly as a place for the worship of Osiris; one could almost call it a Mecca of pilgrims. Osiris, the most human god of the Egyptian pantheon, had been cut into pieces by his rival, Set, or Typhon; but his son Horus had brought him back to life by reconstructing his body. His tomb however, was at Abydos, though we do not know whether it contained the body of the god, or as Greek writers say, only his head.

On account of the sanctity of the place, the Egyptians liked to be buried there, and very few localities contained cemeteries so rich, belonging to all epochs from the neolithic age down to the Roman Empire. Kings had there built temples most of which, excepting two, have been destroyed, though one in particular, built by Séti I, of the nineteenth dynasty, the father of Rameses II, has remained almost in its entirety. It was unearthed by Mariette. It is a large temple which was completed by Rameses. In the part built by Séti there are some of the most beautiful sculptures in Egypt, but from father to son the style changed completely, the work of Rameses being hastily done with the carelessness characterizing so many of his monuments.

The temple of Séti is what is called a memnonium, that is, an edifice in connection with a tomb and in which they rendered services to the dead. Since it is dedicated to Osiris, it seemed probable that the tomb of this god might be in this vicinity.

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[1] Translated by permission from Archives Suisses d'Anthropologie générale, Geneva, May, 1914.

[2] This article consists of two letters which were originally written to the Journal de Genève on Feb. 26 and Mar. 17, 1914, while the excavations were carried on. This explains why they do not agree completely. After an interval of three weeks I could describe new discoveries, and especially that of the edifice, the great pool which I did not suspect when I wrote the first letter.—Ed. N.

For several years M. Petrie had attracted attention to what he called the Osireion. He had discovered a passageway leading to a room ornamented with funereal paintings showing a scene of worship rendered to Osiris. In this passageway was a side door before which M. Petrie was stopped and which he shows upon his map to be a passage leading to the temple of Séti, situated about 80 meters from this door.

Following close upon a number of excavations in these cemeteries, it was decided that we would examine all that was in the space which separated the temple from that door, and we commenced this work two years ago. We first found an inclined corridor, completely filled with débris, whose walls are covered with texts from the Book of the Dead from the time of Menephtah, the son of Rameses II, King of the Exodus. This corridor which was 14 meters long, was formerly covered by a ceiling made of large blocks of sandstone all but one of which have been taken away. It ends in what we first thought to be two lateral chambers. Now we have found that it is a single great hall, with corbelled ceiling and the walls covered with funereal paintings of Menephtah.

Opposite the corridor in the east wall of the hall there is a doorway, the triple lintel of which was found two years ago, composed of three stones 5 meters long. We have found that this doorway crossed a wall 4 meters thick. It seemed as if beyond it we might discern two undiscovered rooms. It was only a lack of funds that stopped us. When we left the place, we had before us a space about 50 meters long covered with sand that must be cleared out to some unknown depth, and close to the temple there was a very high mound made by the excavations of Mariette. This pile has since been removed by the Service of Antiquities. It was evident, however, that we could not reach the Osireion until we had the necessary funds for making the excavation on a large scale. So we did not work during the winter of 1912. One can judge of the importance of the excavation from the fact that to-day we have 639 workmen, two-thirds of whom are children carrying baskets. It is the greatest work that the Egypt Exploration Fund has undertaken.

On December 23 we were installed in two crude brick houses built for us in the desert. My collaborators that year were Mr. Whittemore of Boston, and Messrs. Wainwright and Gibson, both Englishmen. After we had begun, I thought that beyond the door discovered two years ago we might reach the entrance of a passage leading to the subterranean sanctuary, consecrated to what is called the double of Osiris; that is, a kind of bodyless shadow which forms part of the person.

I should never have expected to see what we really unearthed. Between the doorway with enormous lintels and the temple of Séti I is a large edifice evidently built at the time of the pyramids; that is, belonging to the first dynasties. It is very much ruined, but it was constructed of massive materials, the largest that have been found in Egypt in like quantity. It is an edifice unique among those numerous temples and tombs that one finds in the Valley of the Nile.

It is rectangular in shape inclosed by a wall 6 meters thick made in two layers, the outer layer of roughly dressed limestone, and the inner layer of great blocks of very hard red sandstone, bound with dovetails of gray granite. The area thus inclosed is 30 meters long by 20 wide and divided into three parallel naves which are separated by enormous monolithic granite pillars supporting architraves which are mostly 5 meters long. The two side naves had a ceiling of granite monoliths that one could hardly call slabs, for they are more than 2 meters thick. The middle nave was probably open to the sky.

These gigantic colonnades must have produced a very wonderful effect. Even now one is struck with admiration before that majestic simplicity, although very little of the whole edifice remains. There is nothing intact but the corner of the north colonnade. All the rest has been ruthlessly destroyed. It is very probable that the one who set the example was Rameses himself, for he had little respect for the work of his predecessors. Several heavy blocks of granite or sandstone used in the sanctuary of his temple located a little farther along, show by their shape and dimensions where they were obtained. But since Rameses, and perhaps even recently, the destruction has been even more ruthless. These majestic colonnades have become quarries where millstones of all sizes have been cut. Everywhere one sees the trace of wedges which have served to split the granite. Many of these millstones, nearly finished, are still there and weigh several tons. We are obliged to remove these as well as a great number of still larger fragments. This is what noticeably retards the work of excavation. We have not yet reached the flagstones of the flooring. We shall then judge better of the effect of those great monolithic columns and of the architraves which they support.

In the wall of these colonnades there is a series of recesses or cells, 6 of which we have already discovered, and there should be at least 16. They are not large. A man can just stand upright in them, and they were closed by doors probably of wood. One can still see the place for the hinges. I firmly believe that these cells are the exact duplicates of those described in the Book of the Dead as belonging to the celestial dwelling of Osiris. Outside of these cells we find nothing at all in the colonnades; neither an object nor a hieroglyphic sign. This complete absence of ornamentation characterizes the monuments of the period of the pyramids, as also does the style of construction and the enormous materials then employed.

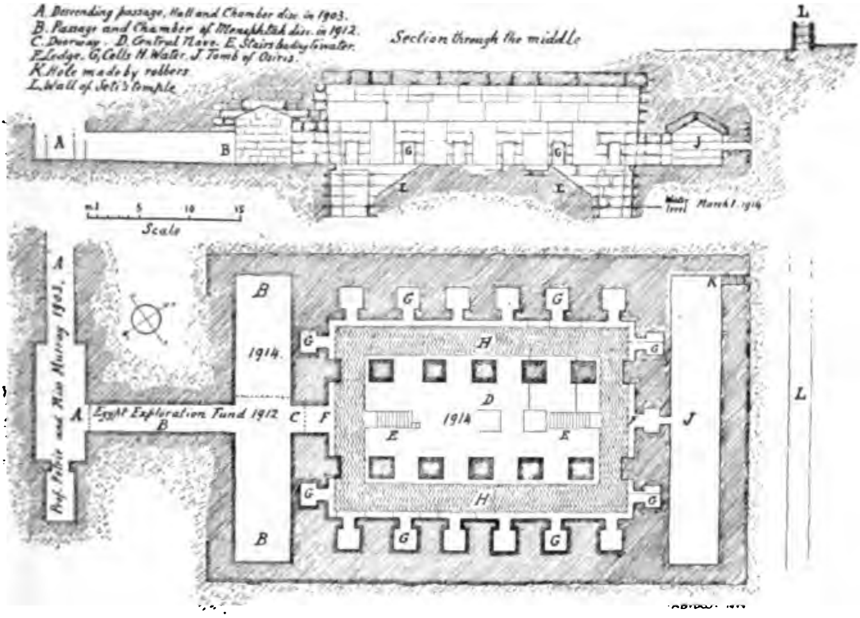
The middle nave terminates at the wall at the end, about 10 meters from the temple of Séti. This wall is of red sandstone, and there alone can be seen sculptures of the King Menephtah of a funereal style. They indicate a tomb. For example, we find there a representation of the two principal amulets that they put on the body of deceased persons. In fact, at the base of the wall, a little door the size of that of the cells opens. When we had crept through the door we found ourselves in a large room of 20 by 5 meters, the ceiling made of heavy blocks. This room, perfectly preserved, is absolutely empty. In a temple which has served as a quarry for centuries nothing can be found. Nevertheless, the texts cut by King Séti I on one of its sides is what proves that it was a funeral chamber. It represents the final scene of a book which is painted or sculptured in the royal tombs, the Book of the Lower World. The tomb of Osiris is really there. Was a sarcophagus there, what was it like, did it contain the body of the god or only his head, that is what we shall probably never know.

We have not yet reached the flooring. It is quite possible that the end of the excavation has some surprise in store for us; that we may learn the purpose of this edifice with three naves which so little resembles a sanctuary.

Next winter, tourists visiting Abydos, after having crossed the temple of Séti, will find themselves before the majestic ruins of one of the most ancient edifices that the soil of Egypt has preserved for us, and which was absolutely unknown up to these last few days. This indicates that this privileged land perhaps still contains under a thick bed of sand some great monuments of whose existence no one had any idea. This is the second time that the explorations through the Egypt Exploration Fund have revealed a style of edifice heretofore unknown. There is reason to hope that results such as those of this winter will awaken the interest of some friends of antiquity in what I will call the great excavation, that which seeks above all things to bring to the light of day these glorious remains of the past and which is not a search for souvenirs destined to decorate the show cases of museums or of private collections.

II. THE GREAT POOL OF ABYDOS.

A short time ago, describing the excavations of Abydos, I said that we had not reached the flooring and that at the end of this work we might find something unexpected. That is just what has happened. We now know the purpose of that peculiar edifice constructed of those huge stone blocks. While at the extreme end the tomb of Osiris was found, the great subterranean room into which we penetrated on the 13th of February, nevertheless the Cyclopean


A. Descending passage, Hall and Chamber disc. in 1903.
B. Passage and Chamber of Menephtah disc. in 1912.
C. Doorway. D. Central Nave. E. Stairs leading to water.
F. Ledge. G. Cells H. Water. J. Tomb of Osiris.
K. Hole made by robbers
L. Wall of Seti's temple
Section through the middle
A
B
G
G
E
E
J
L
Water level March 1. 1914
m.1 5 10 15
Scale
A
Prof. Petrie and Miss Murray 1903.
A
Egypt Exploration Fund 1912
B
B
1914.
B
C
F
D
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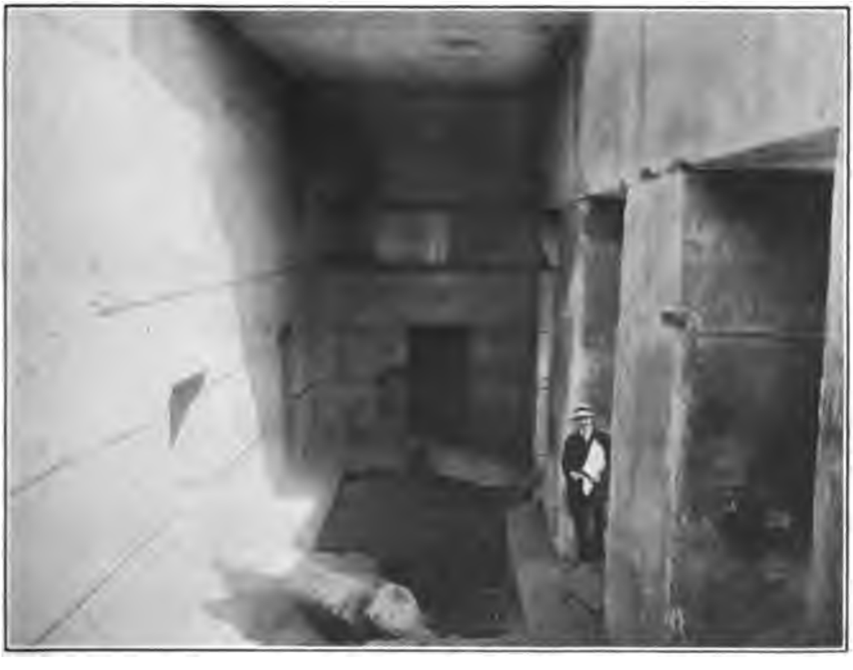
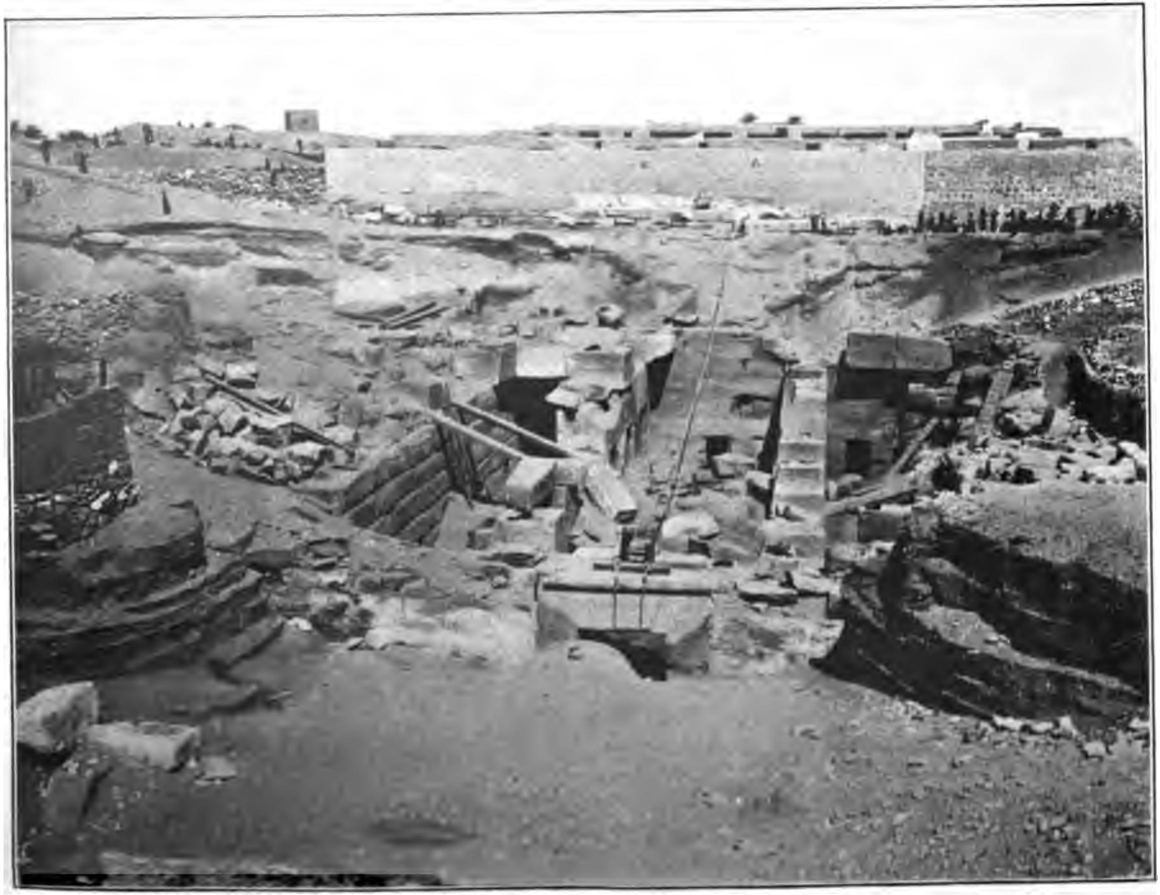
Plan of the great pool and of the tomb of Osiris.



INTERIOR OF NORTHERN COLONNADE, SHOWING DOORS OF THREE CELLS; THE FOOT OF THE LADDER IN THE CORNER RESTS IN THE WATER OF THE POOL.



GENERAL VIEW OF THE GREAT POOL. THE DOOR IN THE END WALL OF THE MIDDLE PART IS THE DOOR OF THE TOMB OF OSIRIS.

construction which is in front of that room is neither a sanctuary nor a tomb; it is a great reservoir, or, if you wish to call it so, a pool, the word being understood in the same sense as when we speak of the pool of Bethesda.

I recall that we found ourselves in a rectangular space of 30 by 20 meters, inclosed by a wall 6 meters thick, the outer face of the wall of limestone and the inner face of very hard, red sandstone. This space is divided into three naves, the two on the sides being narrower than the center one. These naves are separated by colonnades made of enormous pillars of granite supporting architraves equally massive. The two lateral naves had a ceiling, a corner of which is still standing; as for the middle nave, that is more doubtful.

All around this inclosure there are parallel cells in which a man can stand upright, closed in probably by wooden doors and which are without any ornament. It seemed at first sight quite certain that these cells opened on a pavement and that the entire building had a flooring. Great was our astonishment when we discovered that in front of these cells there was no flooring but only a footpath a little more than 60 centimeters wide which extended all around the edifice, passing before the large entrance door, and which ran also along the side of each nave opposite the doors of these cells. This wall of magnificent masonry continues beneath the pathway and at a depth of nearly 4 meters we discovered infiltration water at the level where it is encountered in cultivated land, although we are in the desert.

Thus the two large lateral naves and the contiguous extremities of the middle one form a great rectangular basin bordered on two sides by a stone path which might have served as a towpath for hauling the boats or canoes in the basin and which stopped, perhaps, before the cells.

The middle nave was larger and contained no water except at its ends. From each side the stone forming the footpath, which is an enormous block, passes between the pillars or supports them and advances almost to the middle of the nave to that which at first sight appeared to be a narrow canal, a little more than a meter and a half wide. While digging in this canal we came to two stairways, turned, one toward the front entrance the other toward the funeral chamber of Osiris. We had a great deal of trouble excavating in this middle nave covered with enormous stones that we were obliged to remove, but it is clear from the arrangement of the place that the entire central gallery was an island reached by a wooden bridge or by boat. The end of one of these staircases that we have been able to clear stops about a meter above the water. If we were in a normal year instead of a year when the water is exceptionally low, the staircase would reach the water and, according to the conditions of the season, the first two or three steps even might be inundated.

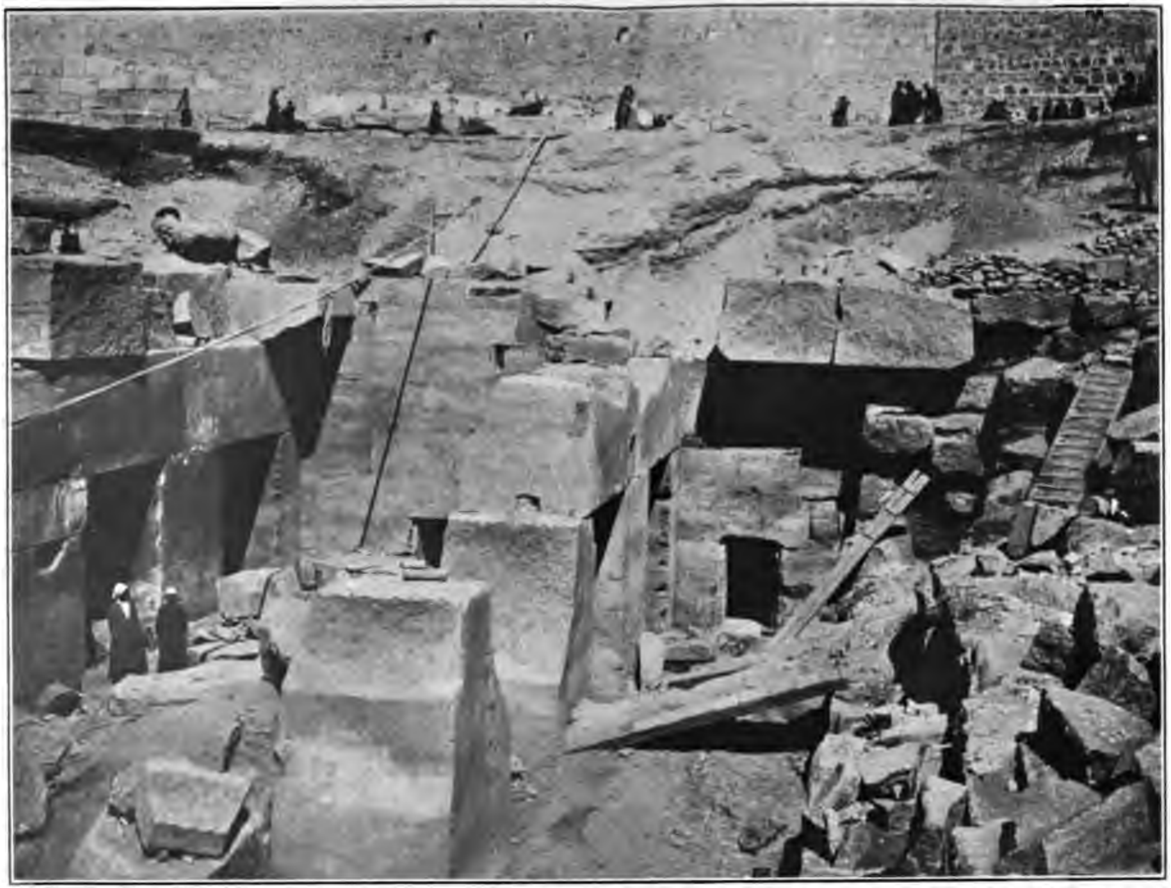
There is no longer any doubt, then, that we have discovered what Strabo calls the well or the fountain of Abydos. He spoke of it as being near the temple, at a great depth, and remarkable for some corridors whose ceilings were formed of enormous monolithic blocks. That is exactly what we have found.

These cells were 17 in number, 6 on each of the long sides. There was one in the middle of the wall at the back; in passing through it one came in the rear to the large hall which was the tomb of Osiris. A careful study of the sculptures confirmed the opinion that this was a funeral hall where the remains of the god were expected to be found. But this hall did not form a part of the original edifice. It must have been constructed under ground when Séti I built the temple of the god. The tomb of Osiris was very near the great reservoir. Nothing revealed its presence; the entrance to it was exactly like that to all the other cells, the back of it being walled up after they had dug through it.

The discovery of this subterranean reservoir, constructed of huge building stones, presents many questions, some of which let us hope may be solved by the completion of these excavations. At present we are checked. We could not get to the bottom of the basin, as it is obstructed by a number of large blocks thrown there at the time the edifice was destroyed. There are some millstones weighing several tons and other fragments just as heavy. We must get to the bottom in order to find out where the wall of magnificent masonry inclosing the water may lead, whether it ends at a flagstone pavement, and also whence comes the abundant supply of water that we see in our excavations. Hydraulic engineers are now studying the sheet of water which extends under Egypt, under the desert as well as under cultivated land. Is it that water that we find in the reservoir? Or has it a conduit which emanates from no one knows where? The word that Strabo uses might apply to a spring.

We have as yet no certain indications of the date of the construction; but the style, the size of the materials, the complete absence of all ornamentation, all indicate very great antiquity. Up to the present time what is called the temple of the Sphinx at Gizeh has always been considered one of the most ancient edifices of Egypt. It is contemporaneous with the pyramid of Chefren. The reservoir of Abydos being of a similar composition, but of much larger materials, is of a still more archaic character, and I would not be surprised if this were the most ancient architectural structure in Egypt. The pyramids are perhaps of the same age, but a pyramid is simply a mass of stone and is not a complicated design like the reservoir.

If we have here the most ancient Egyptian structure that has been preserved to us, it is curious that it should be neither a temple nor a



THE GREAT POOL OF OSIRIS, SHOWING THE HUGE PILLARS AND PART OF THE NORTHERN COLONNADE WHERE A PORTION OF THE CEILING IS LEFT.

tomb, but a reservoir, a great hydraulic work. This shows that the ancients well understood the flow of subterranean waters, the laws which control their rise and fall. It is very probable that this reservoir played some rôle in the worship of Osiris. The cells are perhaps those which appear in the Book of the Dead; it is possible also that the water was believed to have a curative property and that it was of service to invalids who came there to seek a cure. Did the barque of Osiris sometimes float on this reservoir, towed by the priests who followed the footpath?—for the solar barque such as one sees in the tombs of kings was always pulled along by a tow line, stopping at some of the doors or chambers. Such are the questions which arise and to which we can not yet reply.

The few travelers who have already seen the reservoir of Abydos have been struck with the grandeur and dignity of the edifice, in spite of the ruined condition in which it was found. Who would have thought a few months ago that at 10 meters underground there would appear a structure such as this, surpassing in grandeur the most colossal Cyclopean edifices? What a strange country this Egypt is! We were beginning to believe that we had found all the great structures and that nothing more remained to be discovered. Who can say that this region does not conceal beneath the ground some majestic work of the most ancient Egyptians that may bring surprises as astonishing as those of Abydos?

AN EXAMINATION OF CHINESE BRONZES,

KU T'UNG CH'I K'AO.

By John C. Ferguson.

[With 14 plates.]

PRELIMINARY NOTE.

It is important that, in all branches of Chinese art, the rest of the world should understand the Chinese point of view. Without a careful survey of the historical development of the country it is impossible to enter into the intricacies of their art interpretation, but general principles can be learned by persons unfamiliar with the language of China if these are translated into our own language. There is a greater lack of accurate information concerning bronzes than in any other field of Chinese art, and this is not for the reason that Chinese literature is not rich in books on this subject. The purpose of this article is to bring to the attention of the western world a succinct authoritative statement of the principles recognized by Chinese connoisseurs in the examination of Chinese bronzes. The original text is written in short nervous sentences which I have frequently joined together to make the meaning clearer. The article demands careful study for a clear comprehension of its meaning.

AUTHORSHIP AND TEXT.

The following account was written in 1767 by Liang T'ung-shu, the son of Liang Shih-chêng, a noted official of the reign of Chien Lung, who was an eminent authority in archeological research, especially in connection with the places around the West Lake Hangchow. The son was employed in the palace as an expert. This account was in manuscript and was only published in 1913 by the Shen Cho Kuo Kuan She, Shanghai, in its encyclopedia of fine arts—Mei Shu Ts'ung Shu. So little has been written on this subject that the following translation may be of some value to the increasing number of students of this interesting branch of ancient art.

Translation of Text.

INTRODUCTION.

What are now called antiques are the gold and silver inlaid bronzes of the Shang dynasty[1] and the ting, tsun and i of King Wên, which were also of ancient workmanship, and therefore correctly classified as belonging to the Shang and Chow periods. The men of the Han dynasty were fond of the craftsman's art, as is shown by the jade pieces of that period, which are of rare workmanship. It was near to the period of antiquity, and the models of the three dynasties could be readily utilized. The articles produced were named after the period of their pattern, and are not necessarily to be considered as genuine products of the Shang and Chow dynasties. There are also articles which have been fraudulently said to have come from ancient tombs, such as the instance of the Hunan amulets; but such facts are well known to connoisseurs. Articles used in the Han period, like the Po-shan censers, having no distinct coloring of blue or green are not classed as ancient, but as belonging to the Han dynasty; but it must be remembered that the output of mortuary articles during the three dynasties was very great and that they were not much used during the Han. Therefore few articles were then buried, and even in the case of those which were buried the blue and green color must be very much like that of the articles of the three dynasties, for the difference in age is not great. Even jades which are now found with bloodlike marks come from the Han period, and how could it be possible that bronzes could be buried without undergoing a change of color?

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[1] Early Chinese dynasties: Hsia, B. C. 2205–1766; Shang, 1766–1122; Chow, 1122–255 (the preceding three dynasties known as the San Tai); Ts'in, 255–206; Han, B. C. 206 to A. D. 221.

THE COLOR OF ANCIENT BRONZES.

Ancient vessels which have been much exposed to the air become blue, while those much exposed to water become green. When exposed both to air and water, the colors blue and green are both produced. The tombs of the ancient kings and emperors were solidly built, so that water could not penetrate them. Those vessels that were placed on stone pedestals were in the air as long as the pedestal remained intact. Thus, being long subject to the influence of the surrounding air, the color became very pure, and, furthermore, there being no contact with the earth, the color is a pure (kingfisher) blue. This is the best variety. Inferior to this are vessels found in the burial mounds of the ministers of state, where they were subject to the influences of the soil and water, and thus were colored both blue and green. The pure green ones were produced where they lay in water without being covered with the soil.

THE DIFFERENCES OF APPEARANCE PRODUCED BY BURIAL IN EARTH OR WATER AND BY EXPOSURE TO THE AIR.

Bronze vessels buried in the earth for a thousand years become pure blue, like that of the kingfisher. The color before noon is pale, but after noon takes on the appearance of clouds, and the kingfisher blue seems as if it would liquefy into drops. There are also places where the earth has eaten into the metal, either making a hole or forming scales and giving the appearance of snail tracks. An appearance of being the mark of a stroke of a hammer is unreal.

Bronze vessels subject to the influences of water for a thousand years become pure green, as the rind of a melon (kua-p'i), and glossy like jade. If subjected to such influences for a shorter time, although they may be bluish green, yet they are not bright. Corroded places are similar to those mentioned in the preceding paragraph.

It is the present custom to call "ancient" light-weighted specimens of either of the above classes. This is done in ignorance of the fact that large vessels are necessarily thick, and that only a third of such vessels are corroded even during a long period of time. The weight of these vessels in which the bronze has only been partially corroded is only reduced by a third or a half. In the case of light, thin vessels, where the influences of earth or water have easily penetrated the entire body of the bronze, the color of bronze can not be seen when fractures have been made by the strokes of hoes. It is all blue or green, or there is an occasional streak of red, like red lead. However, the resonance of the metal is not lost.

Such specimens as have not been covered with earth or water and have been preserved to the present time have a dark brown color with red scales. These scales stand out like good Chen-chow sand. If immersed in hot water for a good length of time, the patina of these scales becomes more brilliant. Such specimens are of the highest value. Spurious specimens can be detected, as their color is only superficial.

None of the three classes mentioned above have any rank odor, with the exception of those recently exhumed from old soil, which retain a strong smell of earth for a short period. Spurious specimens, when rubbed briskly with the palm of the hand, have a distinct disagreeable smell.

COLOR AND PATTERN.

Specimens of a dark reddish or black lacquer color that have been buried in the soil or in water for a short time may become superficially beautiful, but the beauty is not deep and they are never glossy. Such specimens are of secondary value. I have noticed that Han dynasty seals and coins which are fifteen hundred or sixteen hundred years old are rarely glossy even when they are quite green; neither do they have red scales raised upon them. Ancient specimens of bronze in which the patina has penetrated deeply are glossy like jade and have red scales, thus showing that they belong to the three dynasties (Hsia, Shang, Chow). To determine their age, attention must be paid to the gloss of specimens and then to their pattern.

DETERMINATION OF INSCRIPTIONS.

Inscriptions are of two different kinds, k'uan and chi. What is called chuan (seal characters, ornamental writing) is for the commemoration of merit. This writing is on bells and tripods. K'uan is in intaglio, and such writing during the three dynasties was considered stylish. The characters were sunk into the metal. From the time of the Han dynasty, the chi in relief was used, with occasional use, also, of sunken characters incised by the use of tools in the same manner as if on stone tablets. Sunken chi were difficult to cast, but relief chi were easy, and thus it can be easily detected that they did not long belong to the period of the three dynasties. The k'uan of ancient vessels were on the inside and sunken. The chi were on the outside and were in relief. Vessels of the Hsia and Chow dynasties had either chi or k'uan, while those of the Shang dynasty usually had chi, but no k'uan. The ancients showed great care in their work. Artisans were classed by them as among the four estates of the people, and were not looked down upon as in later degenerate days.

In casting vessels the ancients used wax for their models or patterns, and the lines were thin, like hairs—even, regular, and distinct. The characters of chi were rounding like the surface of inverted tiles. They were not deep or bold, and both large and small characters had the same depth. They were clear and distinct, without any blurs. Such castings of carefully chosen bronze were excellent. They had three characteristics: First, they had no marks of sand granules; second, the workmanship was wonderful, and third, there was no sparing of labor. They were not made overnight. If ancient vessels are now found with the k'uan and chi blurred and distorted and cast in an irregular mold, these are the work of amateurs or imitators. The quality of the metal, its color and odor, are not the same as of good vessels.

EXAMINATION AS TO AGE NOT SOLELY DEPENDENT UPON K'UAN AND CHI.

The ancients used sacrificial vessels, such as bells and tripods, for the praise of meritorious and worthy deeds, and hence made inscriptions on them. Inscriptions were put on platters and bowls when they were used in preparation for sacrifices, but when used for domestic purposes inscriptions were often lacking, and such fact can not be used as a proof of their being counterfeits. In such cases the style of the inscription, the quality, color, and odor of the metal must decide.

VESSELS OF THE THREE DYNASTIES.

The Hsia dynasty was noted for reliability, the Shang for quality, and the Chow for display; and the bronze vessels of these dynasties have the same respective differences. Vessels of the Shang dynasty are plain and without adornment, those of the Chow dynasty are finely engraved, while those of the Hsia are different from either of these. I have often seen vessels of the Hsia dynasty on which gold was inlaid thin as hairs. In course of time the gold fell out, leaving sunken places, so that the ornamentation became depressions. Such inlaying is now often wrongly attributed to the Shang dynasty by those whose knowledge is limited. They should remember the poetical quotation—

> Engraved and chiseled are the ornaments,
> Of metal and of jade is their substance.
> —Shih King III, 1, 4, 5.

and thus know that these were of the three dynasties period.

NEW BRONZE VESSELS.

New bronze vessels refers to those cast during the T'ang, Sung, and Yuan dynasties. From the time of the Emperor Yuan Pao (742–756) of the T'ang dynasty, down through the Sung dynasties, such vessels were made at Ku-yüng. Many were also made at T'ai Chow, but these were chiefly of the small lui-wen pattern. During the Yuan dynasty, Chiang Lang-tzu, of Hangchow, and Lu Wang-chi, of Ping Chiang, were noted artisans, but the figures on their work were without delicacy. However, Chiang was a better workman than Lu.

METHOD OF DETERMINING ANCIENT BRONZE VESSELS ADOPTED BY THE HOUSEHOLD DEPARTMENT OF THE CHING DYNASTY.

Vessels of the Shang dynasty were unadorned, those of the Chow dynasty were richly engraved with fine lines, while those of the Hsia dynasty were inlaid with gold which had the appearance of fine hairs. These fundamental facts can not be overlooked.

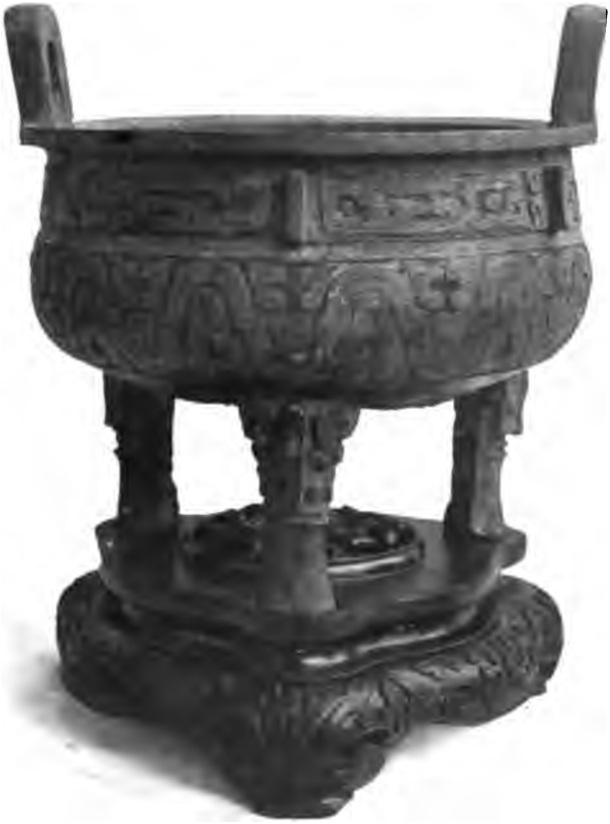
The inscriptions on chung, ting, tsun, and i during the Hsia, Shang, and early part of the Chow dynasty had only 1 or 2 characters, and at the most 20 or 30. Long inscriptions of two or three hundred characters belong to the later part of the Chow dynasty or to the early Ts'in. There were also genuine vessels of the three dynasties which bore no inscription, for the reason that they were the property of families which had no special merit to be commemorated. Such vessels can not be discarded as spurious. The characters used in inscriptions of the Hsia dynasty were niao chi (bird tracks), those of Shang were ch'ung-yü (insects and fish), while those of Chow were ch'ung-yü and the large "seal." Ts'in dynasty used the large and small "seal" characters, but from the Han dynasty onward small seal characters were used. The three dynasties used sunken inscriptions, while the Ts'in and Han used inscriptions in relief, and occasionally sunken ones, which were incised with tools in the same manner as stone tablets, for the reason that this was easier than casting inscriptions in intaglio.

Ts'ao Chung-ming says that bronze vessels buried in the earth for a thousand years became pure blue like the kingfisher, while those subject to the influence of water for a thousand years became clear green as the rind of a melon. My opinion is that where the soil is warm and moist vessels became blue and where the water is brackish they became green. It is also said that before a thousand years vessels may become blue or green, but not glossy; but I fear that this is not true. How can it be that vessels of a thousand years of age which are glossy, but on which the blue and green colors are not pure, are not properly classed as belonging to the three dynasties? Kao Shen-fu considered that where the metal was comparatively pure and without much alloy the vessels became blue, and that when the alloy was in larger proportion they became green. But the ancients were not niggardly in their expenditures, and how can it be thought that they preferred alloyed metals? Such statements are those of a blind man at a theater, and should be discounted. There are those also who maintain that vessels of a dark-brown color have not been preserved in open places, but have come from graves on hillsides or stone vaults where there is no dampness to cause the decaying corpses to influence the color of the metal, and this opinion is probably correct.

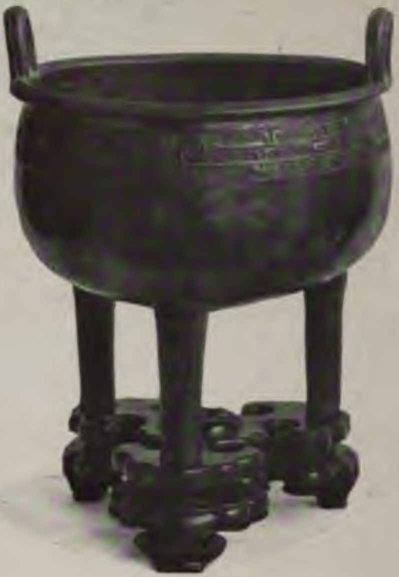
The sound given out by ancient bronzes is clear, while that of modern pieces is confused and noisy. Ancient bronzes have no rank odor, except those which have been recently taken from the soil and still retain its smell. Other kinds are spurious. If rubbed briskly with the palm of the hand, a rank odor is given off.

The ancients were not sparing of labor like the artisans of later degenerate times. For this reason the k'uan and chi of ancient bronzes were fine like hairs and were even, regular, and distinct without a trace of being blurred. The characters of the chi were rounding like the surface of inverted tiles and were uniform in depth, both when written large or small. The specimens preserved by me all have these characteristics, but I have seen those preserved by others which are different. If the inscriptions are somewhat blurred, such specimens are spurious, and the quality and color of the metal would also be incorrect.

The best color of ancient bronzes, according to some persons, is dark brown, and in my opinion the worst is a leaden color. Those which have red scales are better than the lead-colored ones, but the dark-brown color is still better. The dark-brown color is not so good as the green, nor the green as the blue, nor the blue as those which are iridescent (mercurial), or the iridescent as the black lacquered ones, which, however, have the fault of being easy to counterfeit. Such counterfeits can be readily detected.



Tripod bronze vessel of Chow Dynasty, known as the K'o Ting; supported on wooden stand. Height 9⅛ inches, diameter of mouth 9⅜ inches. (Ferguson collection.)



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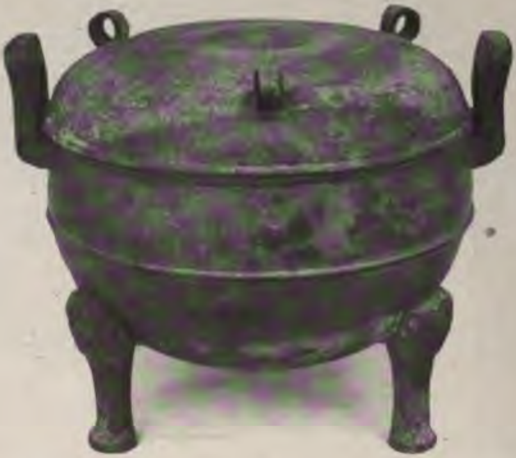
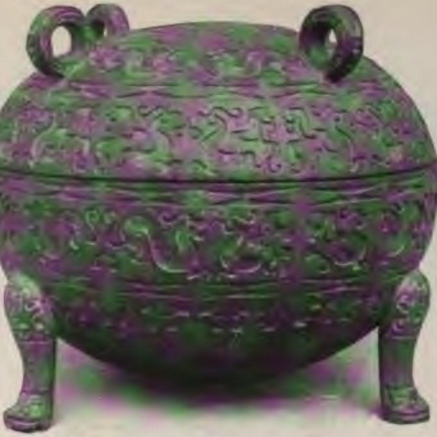


2.

1. Tripod bronze vessel of Chow Dynasty, known as a Lui Wĕn Ting, decorated with thunder scroll; supported on wooden stand. Height 6⅝ inches, diameter of mouth 5⅛ inches. (Ferguson collection.)
2. Covered tripod bronze vessel with three suspending rings on cover, of Han Dynasty. (Metropolitan Museum, New York.)



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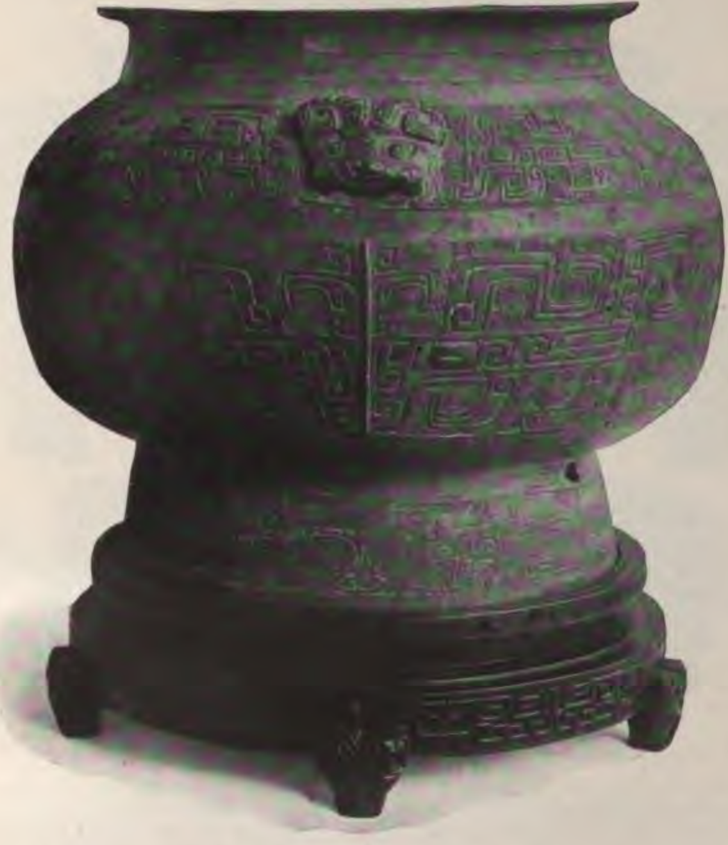
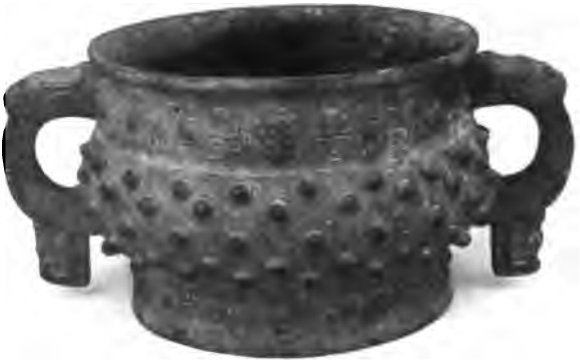


2.

1. Covered tripod bronze vessel, of Shang Dynasty, decorated with pinniped pattern—k'uei wên; four suspending rings on cover; color of bronze is mercurial and is iridescent. Height 6¼ inches, diameter of mouth 7 inches. (Metropolitan Museum, New York.)
2. Bronze wine vessel, of Chow Dynasty, known as Fu Hsin Lui; inscription on rim; decoration of the p'an k'uei pattern; supported on wooden stand. Height 8¾ inches, diameter of mouth 7⅝ inches. (Ferguson collection.)



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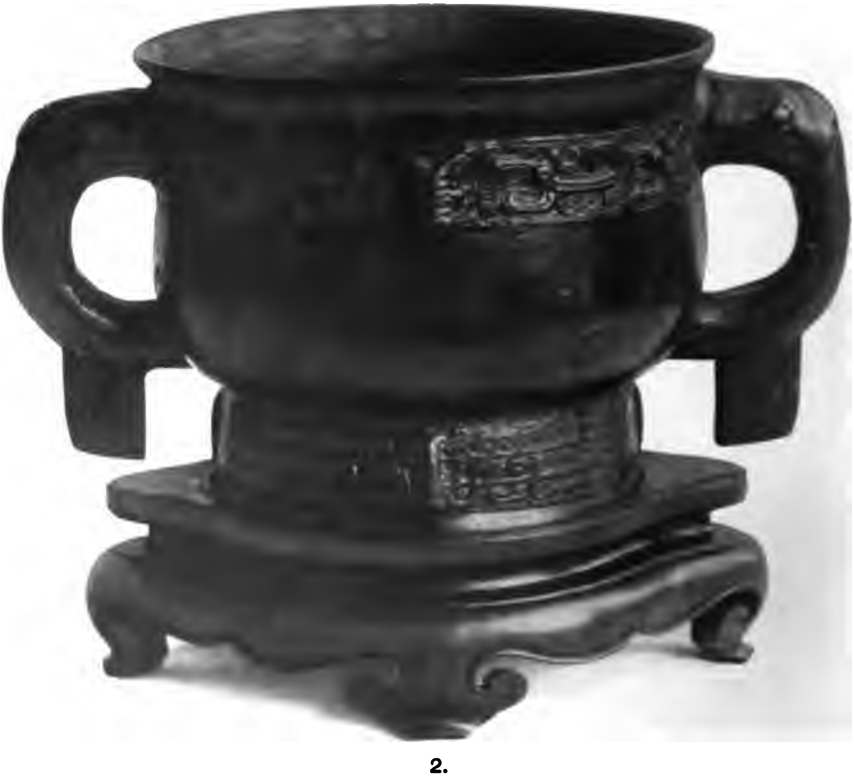
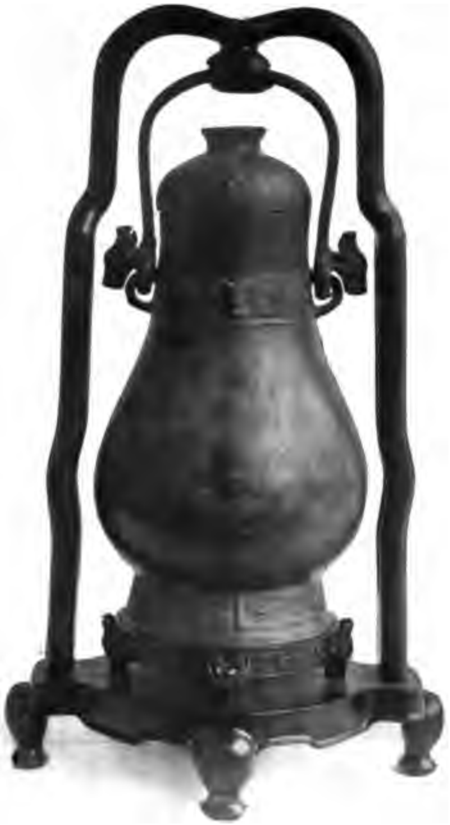


2.

1. Bronze wine vessel, of Shang Dynasty, decorated above and below with recurved pattern—hui wên. In center are nipples surrounded by diapers. Handles richly carved and surmounted by ogre's head. Height 5¾ inches, diameter of mouth 8 inches. (Metropolitan Museum, New York.)
2. Bronze wine vessel, of Chow Dynasty, decorated with the thunder scroll—lui wên, and known as the Fu Ting I; has a cast inscription. Height 5¼ inches, diameter of mouth 6¼ inches. (Ferguson collection.)



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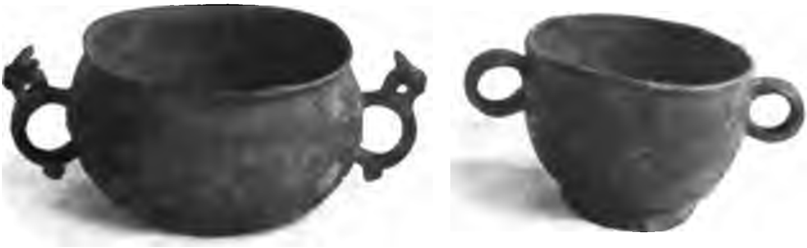
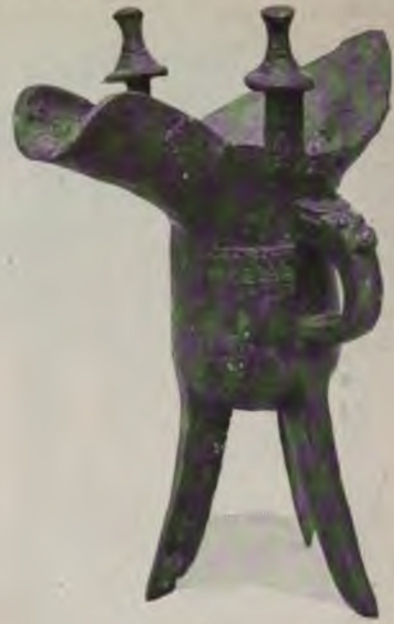


2.

1. Bronze wine vessel, of Shang Dynasty, known as Kung Fu Keng Yu, shaped like a bow, with inscription on inside of cover and on inner base of vessel, ends of handle decorated with an animal head; supported on wooden stand with overreaching frame; is recorded in Chun Ku Lu. Height 1 foot 2 inches, diameter of mouth 3¼ inches. (Cleveland Museum.)
2. Two small bronze wine vessels, of Chow Dynasty, known as Chou. Neither one is decorated, but that on left has animal head on the two handles. (Larger one in Ferguson collection; smaller one in Cleveland Museum.)



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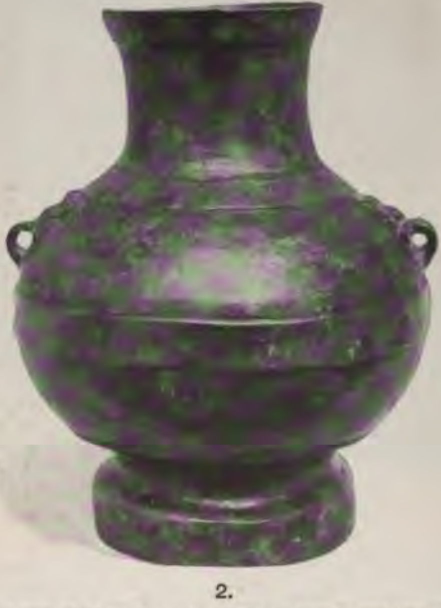
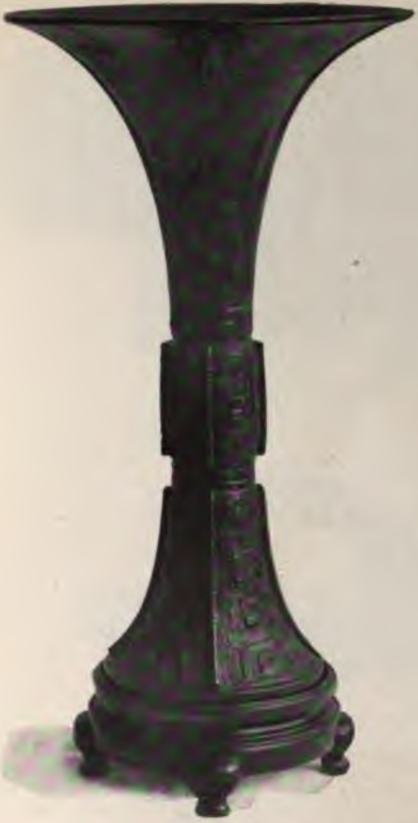


2.

1. Bronze libation cup, of Chow Dynasty, with one handle and two suspending hooks, known as Fu I Tsioh, with an inscription under the handle. Height 6½ inches. (Metropolitan Museum, New York.)
2. Bronze wine vessel, of Chow Dynasty, known as Su Hu; supported on wooden stand, with two suspending rings decorated with an animal head, with two bands around body of [illegible] Height 1 foot 7 inches. (Metropolitan Museum, New York.)



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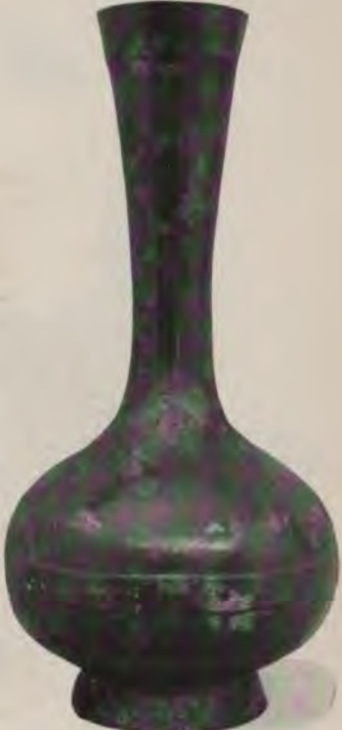
1. Bronze vase, of Chow Dynasty, known as a Ku; is supported on wooden stand. Height 9 inches. (Ferguson collection.)



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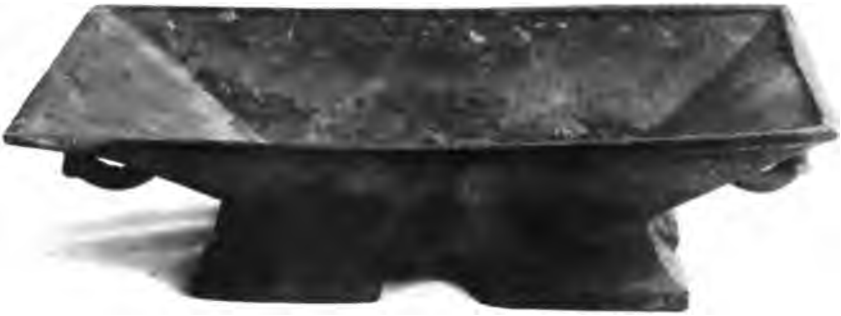
2. Bronze vase, of Han Dynasty, undecorated, with band around body of vessel. Height 1 foot 2⅛ inches, diameter of mouth 3⅛ inches. (Metropolitan Museum, New York.)



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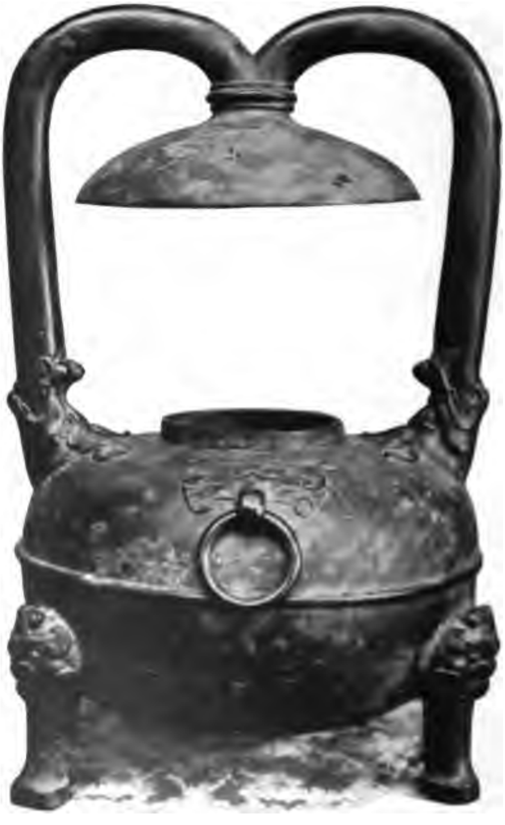
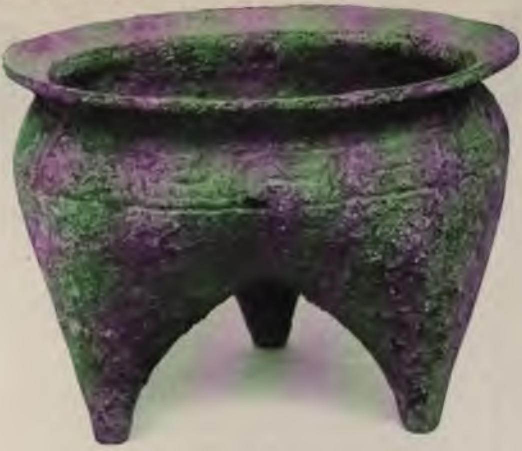


2.

1. Bronze sacrificial platter, known as Fu, of Chow Dynasty; illegible inscription; with two handles. (Ferguson collection.)
2. Bronze tripod wine steamer, known as a Ting, of Han Dynasty; top of legs decorated with an animal head, cover missing, hollow tubes above vessel provide exit for evaporation of wine which dripped from overhanging cover. Height 11 inches. (Collection of Mr. Pao Hsi, Peking.)



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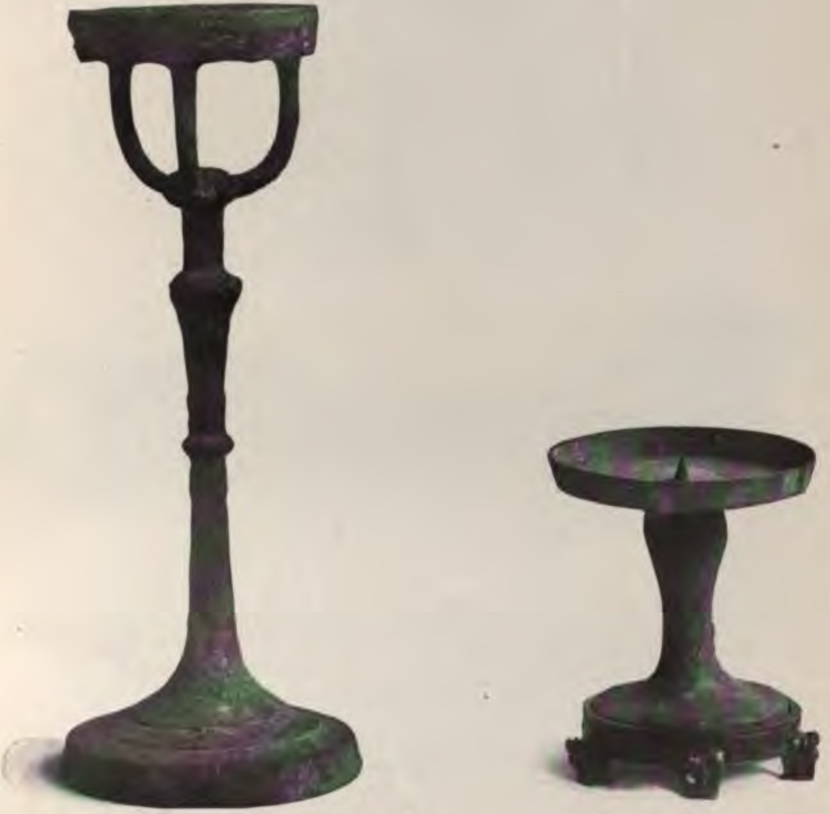
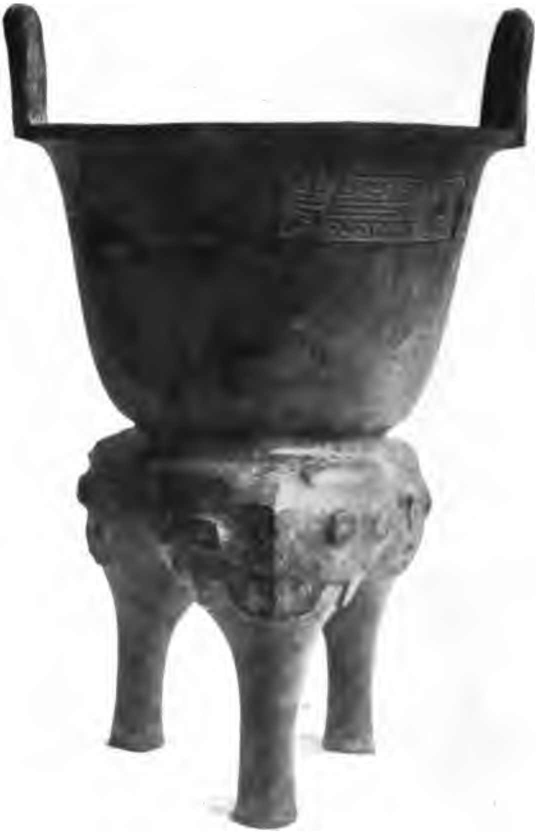


2.

1. Bronze tripod vessel, known as Ko, of the Tsin Dynasty, surface roughened by burial in soft earth. (Metropolitan Museum, New York.)
2. Two bronze candlesticks, known as Têng, of the Han Dynasty; smaller one supported on wooden stand. (Ferguson collection.)



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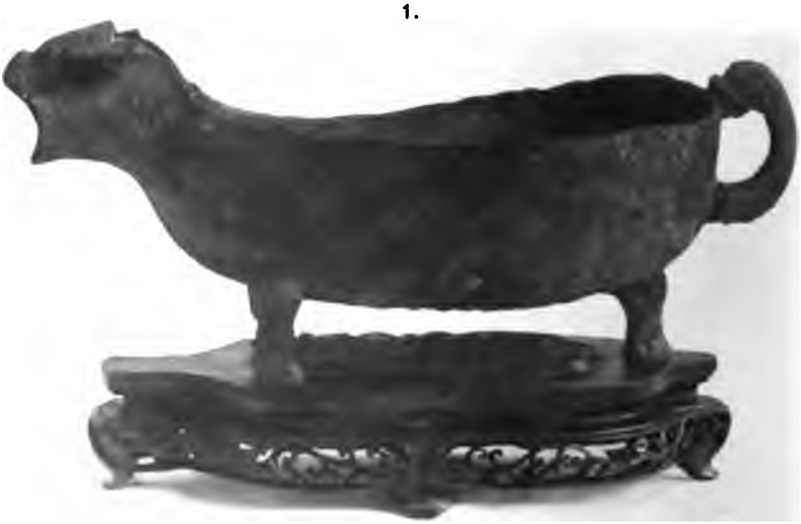

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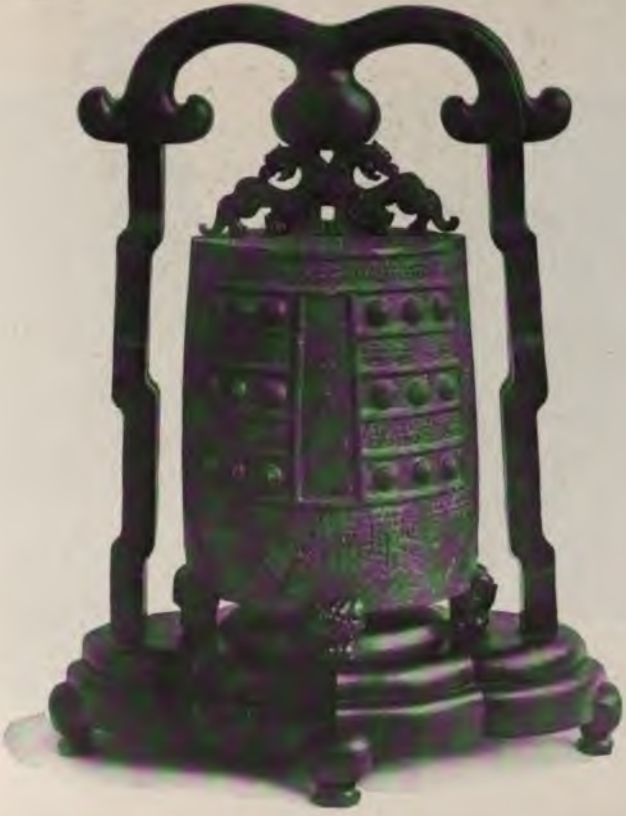
1. Bronze wine cooler, known as Ping Hsien, of Han Dynasty, decorated with pinniped pattern—p'an k'uei. Height 1 foot, 6¾ inches, diameter of mouth 1 foot.
2. Tiger-shaped wine ewer, on three legs, known as Hu Hsing I, of Han Dynasty; supported on wooden stand. Height 3 inches, length 6¼ inches. (Ferguson collection.)



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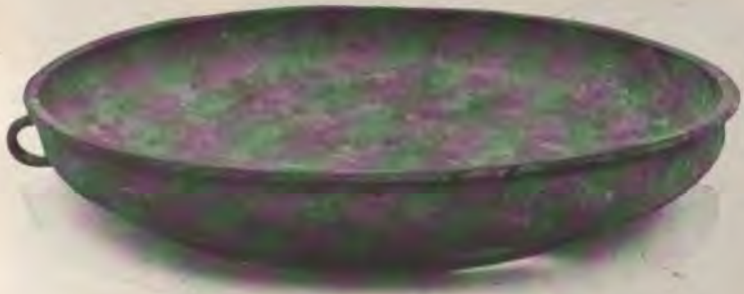
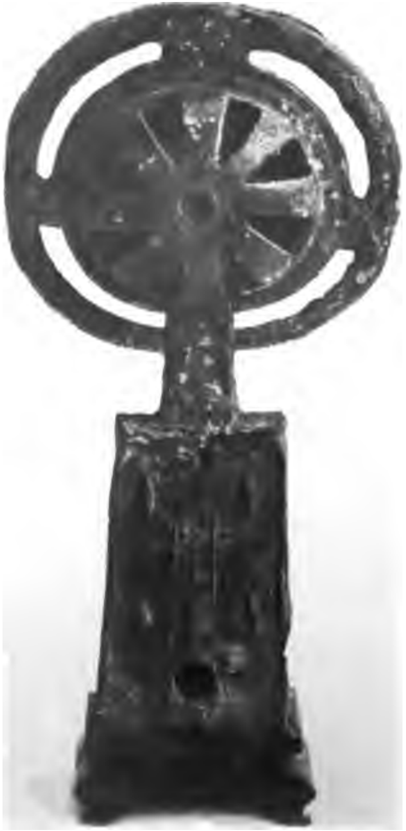


2.

1. Bronze bell, known as Chung, of Chow Dynasty; supported on wooden stand with overreaching frame; double dragon decoration at top. Height 12 inches. (Ferguson collection.)
2. Bronze platter, of Chow Dynasty, known as Ch'i Hou P'an; a part of the most famous bronze sacrificial set in China; has the date 1116 B. C. cast in intaglio on the inside surface of platter. (Metropolitan Museum, New York.)



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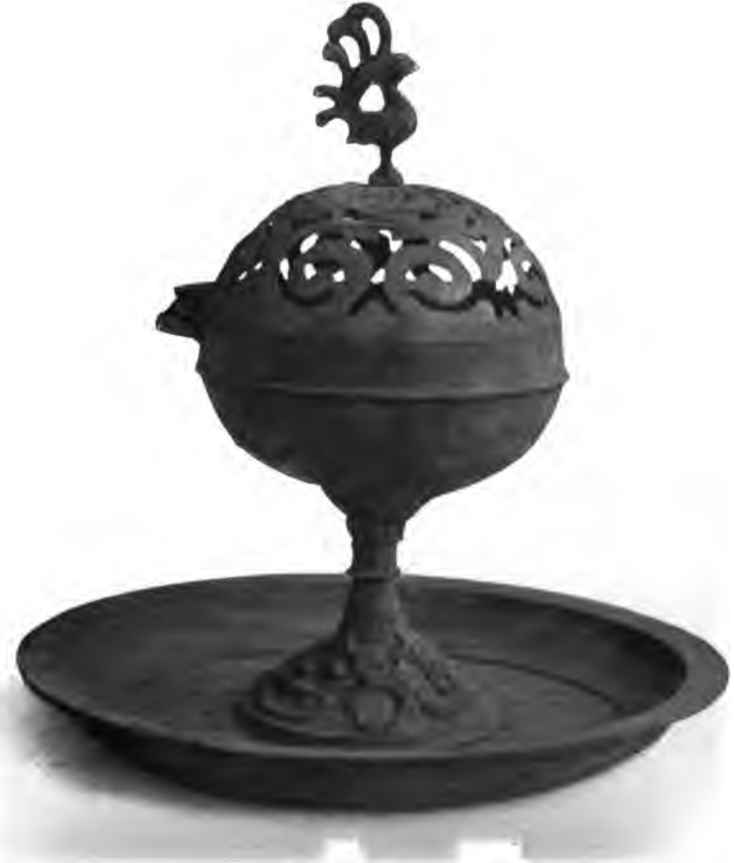
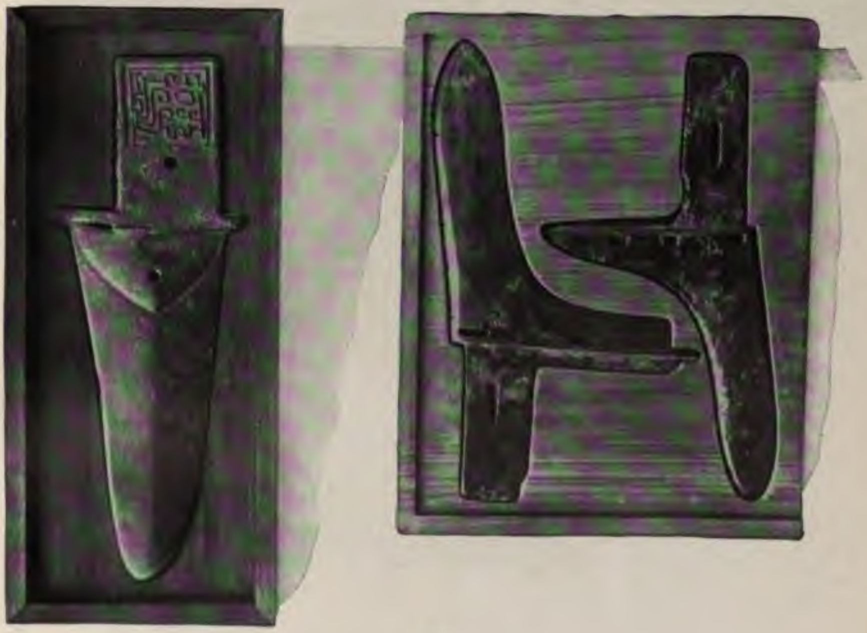


2.

1. Bronze musical rattle, known as Wu Lao, of Chow Dynasty, used for ceremonial dancing; has a loose tongue which rattles when instrument is shaken; supported on wooden stand. (Ferguson collection.)

2. Bronze incense burner, known as Po Shan Lu, of Han Dynasty. Height 9½ inches, diameter of mouth 4½ inches, diameter of plate 9 inches.



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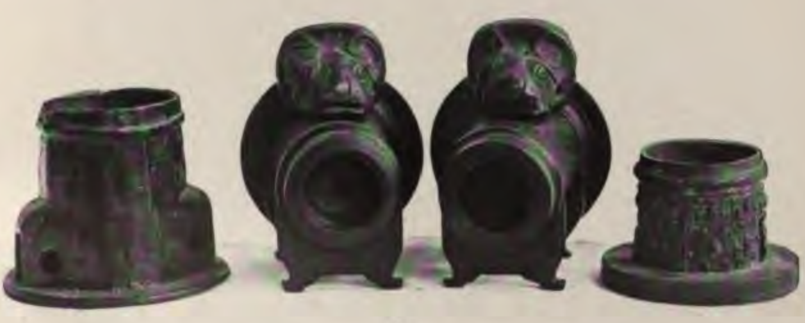
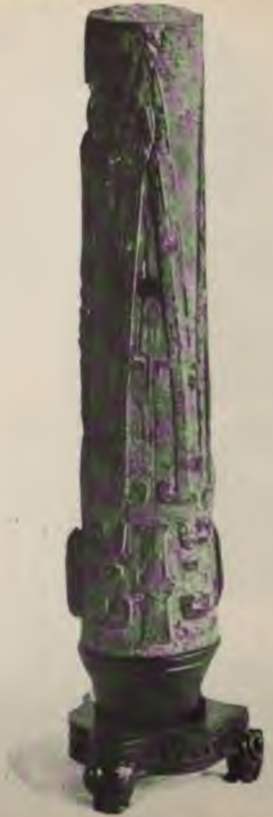


2.

1. Three bronze dagger heads, of Chow Dynasty, with cast inscription. (Ferguson collection.)
2. At either side are two axle ends, of Han Dynasty, one plain and one decorated with thunder scroll—lui wên. The two central pieces are axle pins, of Han Dynasty, supported on a wooden axle. These are decorated with ox heads. (Ferguson collection.)



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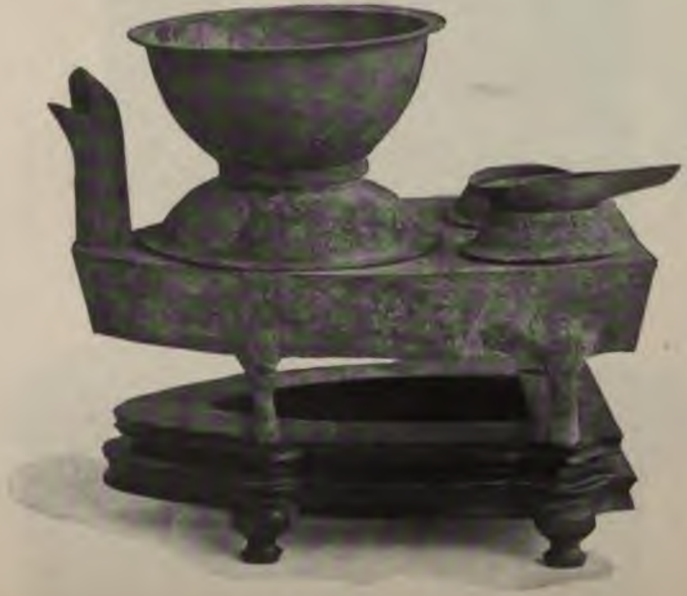

2.

1. Bronze spear handle, of Chow Dynasty, richly ornamented, with a cast inscription on inner side of top; supported on wooden frame. Height 7 inches. (Ferguson collection.)
2. Bronze range with utensils, of Han Dynasty; supported on wooden frame. Height 4½ inches. (Ferguson collection.)

THE RÔLE OF DEPOPULATION, DEFORESTATION, AND MALARIA IN THE DECADENCE OF CERTAIN NATIONS.[1]

By Dr. Felix Regnault.

The persistent decadence of certain peoples is at present attributed to depopulation, deforestation, and malaria. How can these so widely divergent factors be brought into interrelation? To understand it, geology, sylviculture, and medicine must be interrogated.

In the period of her greatness Greece was a fertile, well wooded, healthful, and very populous country, estimated by historians to have had at least 8,000,000 inhabitants.

Two centuries later, at the time of the Roman conquest, the mightiest cities of Greece and the most important leagues could place only a few thousand soldiers in the field, and entire Hellas, according to Plutarch, could equip not more than 3,000 fully armed troops. The country became poor. Polybius estimates the taxable capital of the Peloponnesus at less than 6,000 talents ($7,080,000), the landed and movable property of Athens at 5,750 talents ($6,371,000), being half of the reserve funds of Pericles.

Historians ascribe the depopulation of Hellas to a continuously increasing emigration of adult inhabitants. Since the fourth century B. C. they went forth in throngs to foreign regions as mercenaries; the conquests of Alexander the Great precipitated this exodus and dispersed Greece over the surface of Asia.

Low birth rate probably also played an important part, but we are poorly informed on this subject. The classical instance of the Spartans who, at the time of the Roman conquest, counted only a few hundreds, is not enough, for here is involved only the question of the aristocratic caste, and we do not know whether the plebs had diminished.[2]

Emigration and low birth rate prevailed only for a time. If Greece had conserved its fertile soil, immigration or a higher birth rate would have sprung up at a given moment and filled up the ranks. Depopulation persisted because the land was impoverished by becoming deforested and unhealthy. Strabo observes that in his time nearly all the mountains seen from the coast were denuded, while at the same time the valleys and plains were ravaged by malaria, as Mr. Rose has recently demonstrated.[1]

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[1] Translated by permission from the Revue Scientifique, Paris, Jan. 10, 1914, pp. 46–48.

[2] Possibly it was due to the high birth rate that Greece, down to the sixth century B. C., swarmed over numerous colonies. Families quitted their city to establish new ones. Greece in that way relieved itself of an excess of population and at the same time remained populous. On the other hand, at the end of the fourth century B. C. the emigration of adult people was no longer compensated by an excessive birth rate. Unfortunately we have no certain data on this subject.

Deforestation was a result of the depopulation of the countrysides. In fact, the cultivation of the soil, which the lack of laborers rendered impossible, was replaced by exploiting the elevations, since a few men could superintend immense herds and drive them every summer into the mountains, while the dried-up plain could not support them. The pasturage would not have entailed waste if it had been rationally regulated. But the ignorant and avaricious proprietors overburdened the pastures; the too numerous cattle devoured the herbs down to the roots, trampling and destroying them. With each year the pastures grew more impoverished. To feed a herd which was always so numerous, it was driven into the woods, where the cattle browsed on the young roots, the seedlings—all the future trees. In the long run the old trees perished; occasionally the cattlemen hastened their end by setting them on fire. Then desolation began. The water, no longer held in place by the trees and turf, rushed tearing down the slopes, carrying away the entire vegetal soil; it was the death of the mountains.

With deforestation, malaria developed. Mr. Rose claimed that the Anophele mosquito had been imported into Greece from a foreign land, probably from Egypt. M. Cawadias[2] has demonstrated that swamp fever had always raged in Hellas. At first its area was limited, but deforestation favored its extension. This, in fact, renders the run of rivers unequal. In summer, when there is no flow, the river beds still in places contain pools favorable to the breeding of mosquitoes. It is in this way that the plain of Argos, once healthy and fertile, is ravaged by malaria. On the other hand, silt is deposited at the mouths of the streams, forming vast marshy plains, where the Anophele develops.

The condition of the lakes was altered. The detritus carried by the water over the deforested slopes choked the outlets of the lakes and kept the water on a nearly constant level. Besides, there are long intervals between the high-water and low-water levels, and during the latter period the marshy banks become favorite nests of the Anopheles.

Finally, as another consequence of deforestation, new lakes are formed by the movement of subterranean waters and the breaking up or subsidence of the soil, which are subject to the same conditions and thus produce malaria.

At present Greece has a high birth rate, but since she can not support all her children, they emigrate in large numbers, for the old devastations persist, and innumerable herds perpetuate the work of destruction. During every summer malaria rages. Only the Ionian Islands, which have always remained wooded, rich, and densely populated, can convey an idea of what ancient Greece once was.[1]

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[1] W. H. S. Jones, Malaria and Greek history, with a preface by H. Rose, Cambridge, 1907.

[2] A. Cawadias, La Paludisme dans l'histoire de l'ancienne Grèce. (Bull. Soc. Fr. histoire de la Médicine, 1909, pp. 158

Next to the decadence of Greece may be considered that of Italy. Among the manifold causes which brought about the fall of the Roman Empire may be pointed one of the same order as that which prevailed in ancient Greece. After the Roman conquests the allurements of the city of Rome attracted to it the rural population, [2] and the depopulated lands were acquired by the patricians. Large estates or "latifundia" were thus formed, and the iniquitous rôle which they played is related by ancient writers, without being explained. Here, as in Greece, the scarcity of laborers gave rise to pastoral industry; the herds were a "husbandry of which Jupiter defrayed all the expenses"; the meat sold well. Then, the "caniculi" system of drains, which had been established by the first cultivators in the flat clayey plains of Latium, were neglected and became obstructed. Their very existence was so far forgotten that no Latin work mentions them. Swamps formed, and at the close of the first century B. C. the population of these regions was decimated by malaria.

It was not, as has been claimed, in consequence of wars that these lands were impoverished and ravaged with the plague. Enemies might ruin the crops, the farms; but they would not engage in many long months of labor needed to destroy a work of such magnitude as the "caniculi." After peace the peasants would resume their agricultural pursuits. They would not abandon fertile lands, unless their mentality was changed. Instances of the courageous persistence of the peasant when he is attached to the land are numerous in history. Thus, after the conquest of Algiers, the plains of Metidja, which were occupied by the Arabian herders, were dotted with stagnant pools and ravaged by malaria; the French peasants who set out to cultivate the land were all attacked with fever and many of them died; others continued the work, and after a time the crops absorbed the waters and that country is now healthy and prosperous. It was therefore not the infertility and insalubrity which drove the Roman peasants from these lands, but, on the contrary, the peasants, having lost their attachment to the land, left the country and the lands became sterile and unhealthful.

Italy is at present overpopulated, for the families are large, and the fertile plains of Campania, Apulia, and Tuscany, which in Roman times had been given over to the shepherds, are reconquered by t cultivators. But the regions which had been attacked by malar remain insalubrious and half deserted; they constitute large domai upon which, as in times of the Cæsars, the pastoral industry is st practiced.

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[1] I have furnished numerous facts in support of this theory in "La décadence de la Grèce expliquée par la déforestation et l'impaludisme" (Presse médicale, Sept. 22, 1909, No. 76), and "Le déboisement et la malaria en Grèce" (Le Naturaliste, Paris, 1910, p. 262).

[2] As causes of the depopulation and decadence of the Roman Empire might also be cited the low birth rate, but we are poorly informed on this subject. Certain it is that Augustus promulgated the Pappia Poppoea law, which deprived celibates of the right of inheritance and allowed the childless married people only half of it. But these laws were directed only against the upper classes.

Among the numerous factors causing the decadence of Spain, o of the most important was its depopulation by emigration and i low birth rate. One can imagine what must have been the allur ment of the New World for the men of the sixteenth century—fores of precious woods, diamond mines, rivers with rolling gold san Thus the young people embarked in crowds, and most of them nev returned.

In Europe itself the possessions of Spain extended from Sicily the Baltic. To hold peoples so different from herself under h domination she needed men, and Spain then sent forth the mo vigorous of her children as soldiers. Of those who remained in t country a large number entered the various religious orders. Tho who married, and upon whom fell all the burdens of home affair restricted their offspring, so that the voids could not be filled ou Even the cities became depopulated, notwithstanding the influx more than half a million strangers. In the seventeenth century t decadence was complete. The ruin of the land made it definitive.

As in Greece, as in Italy, so in Spain the depopulation of the cou trysides favored pastoral pursuits. The great landowners, the ma ters of Castilla, drew large revenues from the rearing of the meri sheep, whose wool yielded an annual return of 10 francs per hea Their powerful corporation, the "Mesta," obtained exorbitant priv leges from the Government; the flocks, which herded in summer o the plateaus, in winter on the lower levels, everywhere had the righ of way and of watering; fences were forbidden, and the flocks d voured the crops, vines, olive trees, and other verdure. Castilla b came deforested, then denuded, and the rivers were turned into to rents. There was total ruin, and famine permanently reigne "The lark had to import its grain" when passing through this lan of hunger and thirst. Andalusia and Aragon, countries of large prop erties, suffered from the same evils. On the other hand, the north ern Provinces, subject to the régime of small properties, preserve some prosperity, thus establishing a striking counterproof.[1]

In Spain, as in Greece and Italy, the development of the height resulted in deforestation and ruined the soil, but in Castilla, whic is a high plateau whose climate is unfavorable to the reproduction the Anophele mosquito, malaria could not settle; it raged only i certain low and humid districts of Andalusia.

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[1] This theory was presented by me, with numerous historical details, in Les Documents du Progrè Oct., 1910, p. 298. Dr. W. Koeppen, in another article, "Les Causes de la Décadence de l'Espagne et d certains autres pays" (in the Review, June, 1912, p. 387), brought new facts to the support of my thesi

The Kingdom of Spain at present presents the same aspect. Its capital rises in the midst of vast solitudes. Some large proprietors share in the deserts of Castilla and the plains of Andalusia, which continue to be ravaged by their flocks of sheep and goats.

Devastating wars, unjust laws, low morale, depopulation following upon a low birth rate or intense emigration—all these factors, which are often cited by historians to explain decadence, are but passing causes. As long as the richness of the soil is not destroyed prosperity can rapidly return, and the instances of these fluctuations in the greatness of peoples are not rare in history.

But reforestation, restoration of vegetal earth on a denuded soil, turning torrents into peaceful watercourses, the drainage and sanitation of the swamps—these are works which require centuries of constant and devoted labor, the sacrifice of numerous generations. Thus Greece, Italy, and Spain continually suffer from those evils which a single improvident generation could cause, but which are so difficult to combat.

At present we are better equipped against those evils. In the first place, we have grasped their seriousness, which formerly was not understood. Governments devote large sums to reforestation, and patriotic associations lease the pastures and conserve them by limiting the number of cattle. In this way Sologne and the Landes (in France), where in the eighteenth century no tree rose from the ground, were reforested; in Sologne the sylviculturist preserved the seedlings from the voraciousness of the hares by means of wire fences; in Landes they built up the soil, so that the water which rotted the grains would run off.

Malaria is fought by the administration of quinine, by pouring petroleum on the swamps, by barricading doors and windows with wire screens, by the multiplication of dytiscid insects, fishes, birds, and bats, all of which are great destroyers of the mosquito.

Finally, the depopulation which prevails not only in France but in all western Europe no longer results in turning agricultural lands into pastures, thanks to the agricultural implements, which lessen the number of laborers, and to the railways, which rapidly transport the workingmen in harvest time.

This is not to say that depopulation, when pushed to an extreme, is not evil. Thus in certain districts in France with a low birth rate fertile fields are neglected, and the mediocre lands, whose yield would not compensate for the expense involved for labor and in bringing harvesting machines from a distance, are abandoned. But it is certain that the means at present at our disposal make it possible for a country to pass through a crisis of depopulation without quickly becoming, as was formerly the case, the victim of complete ruin.

THE STORY OF THE CHIN.[1]

By Louis Robinson, M. D.[2]

[With 12 plates.]

The human lower jawbone differs in a very essential manner from those found among the rest of the primates—and all other vertebrates—in having its lower anterior border bent downward and forward so as to form a chin. Recent discoveries of the remains of early men, such as the Heidelberg and Piltdown jaws, have informed us that this distinctive shape of the inferior maxilla has increased in a marked degree since the lower stages of man's existence. (See figs. 77–81.)

I propose to discuss in the present article some of the causes which appear to be responsible for this curious deviation from type. That these causes were evolutionary factors of considerable potency becomes fairly evident when we examine further into the facts. The general type of the mandible among terrestrial vertebrates has been curiously uniform from the very earliest times, as may be seen in the illustrations of mesozoic and eocene jaws. (See figs. 1–3.) It is, we may say, fixed or stereotyped to a remarkable degree. This makes the search for evolutionary forces which have so changed it in our own species all the more interesting.

There are certain apparent chins found among other vertebrates, a few typical instances of which, with their probable evolutionary causes it may be interesting to discuss briefly.

The elephant (see fig. 8) has a kind of chin, and among older writers in the preevolutionary days this fact was adduced as showing its superiority to other quadrupeds. But we now know that the elephant's chin is a mere degenerate remnant of the long lower jaw of his ancestors, the tetrabelodon (see fig. 6) and the mastodon (see fig. 7). In the illustrations to which reference is made the process of its downward evolution is plainly shown.

Another interesting example is found in the dugong and its relations. (See figs. 59–61.) Here a little search into paleontology shows that this apparent chin is not, like the elephant's, a relic of decayed functions, but that it has, like that of man, increased and improved with the ages. As seen in the illustrations, the dugong's collateral ancestor, the halitherium, and its big extinct relative, known as Steller's sea cow (*Rhytina gigas*), had "chins" also, but in a less marked form. As a matter of fact the downward prolongation of the mandible in these animals is not a chin comparable with our own at all, but is merely a kind of bony rostrum on which the dugong and its relations wear their horny false teeth. This structure, with its curious change of angle, is more comparable to the bony support of the flamingo's bill than to a human chin. A very curious fact is that we appear to find the nearest resemblance in the whole animal world, whether ancient or modern, to our own mandible in a group of some of the earliest reptiles that have yet been discovered. In the figures 4 and 5 of those strange theromorphs, Pariasaurus and Inostransevia, unearthed by Prof. Amalitzky in the Permian strata on the shores of the northern Dwina, we see an extraordinary chin which resembles our own in several striking anatomical particulars.

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[1] Reprinted by permission from "Knowledge," London, November, 1913.

[2] The illustrations are by Mènie Gowland.

How such a resemblance comes to exist I do not even venture to guess; but most assuredly nature's molding forces, which so shaped the mandibles of these ancient reptiles, were totally different from those cerebral activities largely responsible for the chin of civilized man. We say so more confidently because casts of their skull cavities show that they had no brains to speak of, the whole cerebral chamber being of about the same caliber as the tunnel for the spinal marrow.

When the writer discussed this subject before the British Association at Birmingham, and there suggested that the needs of the mechanism for articulate speech would probably account for the essential changes in man's lower jaw, it was pointed out by Prof. Elliot Smith that man's face differs from those of his nearest congeners in many other particulars quite as remarkable as these. I hope some day to show that most of these other changes have been profoundly influenced, if not actually caused, by structural necessities demanded by articulate speech. To attempt to do so now would take me beyond the scope of the present subject, and I shall therefore confine my attention merely to the changes that have taken place in the mandible.

In the many endeavors that have been made to explain the why and wherefore of the chin, the argument as to its being due to sexual selection deserves most notice. It has been rightly said that the chin is essential to the beauty of the human countenance, and therefore in a choice of mates, those deficient in this direction would be losers in life's race. Arguments from esthetics are very difficult to handle, because of the extraordinary differences in the standards of beauty, not only among different species of the lower animals, but among different nearly related races of men. Who can doubt that among the anthropoid apes there is a type of apish beauty (including the retreating lower jaw) which satisfies the most critical and exacting simian taste in choosing a mate? We need not do more than allude to the peculiar esthetic standards obviously existing a little lower down the scale among the baboons, drills, and mandrils.

A chin is now unquestionably a sine qua non of human beauty. But how did it become so? When did the simian ideal cease to flutter the hearts of our primitive ancestors?

Do we not find that almost all the adorable features which have this disturbing and fateful influence nowadays are based upon and are the sign of some intrinsic quality contributing to racial efficiency which lies behind mere appearance? The lower races are continually, to the great embarrassment of sundry colonial governments, desirous of mating with a superior race differing from them in physique and in color. There can be no question that if the colonists in such cases were not the superior race this evidence of the working of sexual selection would not appear. It would seem, therefore, that the primitive man who was manly and, amongst other manly attributes, had a chin, scored all along the evolutionary line in mating contests over the primitive man who was apelike. The individual or the race which does not recognize the upward stream of tendency in such particulars by instinct alone can not be found upon the surface of this planet.

One argument against the sufficiency of sexual selection in producing a chin is the well-known fact that man in the early stages of his existence muffled up his lower jaw with a beard, which is almost without doubt of purely ornamental value. Hence it would seem that the chin per se as a sexual ornament was a failure. Women, it is true, have not adopted this form of hirsute decoration; but I doubt if this goes far in helping the esthetic argument, since, according to the ideals generally current, a big jaw and formidable chin are nowhere considered an excellent thing in woman. I think we shall find that before esthetics came greatly into play more prosaic evolutionary forces had already exerted pressure upon the lower jawbone and had begun to mold it into the general shape in which we find it now.

A glance at the drawing of the mandible of a chimpanzee (see fig. 62) with the roots of the teeth exposed shows the real status of the chin in the anthropoids. It is mainly formed by two thick bony buttresses supporting the sockets of the lower canine teeth. This apparently was the real physical beginning of the bony chin, or rather was, as it were, the gross concrete foundation upon which evolutionary forces of another kind have based the modern structure.

It is a most remarkable and suggestive fact that after man (or the inframan) had lost his huge lower canines this abundance of bony tissue in the lower edge of the mandible did not disappear, but became more marked as an anatomical feature. (See fig. 64.) From analogy with the elephant, such a degeneration should have taken place at once. That this did not happen is a proof that the part more than justified its continued existence by performing some function of vital importance to the species.

Sir E. Ray Lankester, in one of his delightful scientific causeries, has pointed out that man's chin consists of something more than a bony prominence on the jaw. There is a distinct fleshy pad upon its outer surface, which materially influences its outline and which consists of fatty tissue bound up in little cushionlike compartments almost exactly comparable to the pads on our fingers and toes. Although the esthetic and sex influences may be apparent here rather more than in the bony mandible itself—for who can gainsay the charm of a softly rounded chin?—the probable origin of this cushionlike covering is to be found in the fact that the protruding chin needed a pad for exactly the same reason as do a cricketer's shins. It was into a world full of brutal tumult and hard knocks that the nascent chin first made its appearance. In the prize ring to-day it is a well-known fact that a blow on the chin is the most rapid way of putting your opponent hors de combat; and, moreover, it has become apparent that the nearer the exponent of "the noble art" is in structure to a chimpanzee or gorilla the better chance will he have of wearing the glorious "champion belt of all the world." If we look at the bony structure of the chin in some of the prehistoric jaws we find it of astonishing strength, being stout and buttressed as if to stand terrific violence. This is remarkably shown in Emil Selenka's admirable monograph on primitive jaws, published by Kreidel, of Wiesbaden, in 1903. From the above facts it seems reasonable to infer that man acquired such advantages as a chin can give at his peril; and here again it is suggested that some evolutionary need of exceptional potency molded man's jawbone into its modern shape.

It is when we turn a human mandible round and look at it from the inside and observe the surface beneath the central incisor teeth that we begin to get hints as to the actual functions of the chin and the causes which have led to our deviation from ancestral type. About halfway between the rim of the central tooth sockets and the lower edge there are to be found in practically all European and in most other jawbones two bony prominences known as the genial tubercles. (See fig. 18.) Below them are two somewhat similar prominences, generally much smaller (which often appear as faint convergent ridges), which are also known to anatomists as genial tubercles; but these, I think, we need not consider of any importance in the present argument. They are to be found not only in the lowest savages and in prehistoric men but also in a large number of the apes and other vertebrates; indeed, I have detected apparent traces of them in those strange Permian reptiles of incalculable antiquity to which allusion was made above. They are the points of attachment for a little muscle which appears to be equally developed in man and in many of the lower creatures. It is known as the genio-hyoideus and has no connection with the tongue.

A close examination of the larger bony prominences, or the genial tubercles proper, reveals some very interesting and remarkable facts, especially when we employ comparative methods. To these are attached the tendon of the fanlike genio-glossus muscle which spreads out beneath the whole lower surface of the central region of the tongue and penetrates through the intrinsic muscles almost to the upper surface. (See figs. 64, 65.) Now if we examine any of the current books on anatomy, little or no suggestion is found that the functions of the genio-glossus muscle have to do with articulate speech. Let us leave the mandible for a while and confine our attention to the structure and functions of this muscle, and I think it will soon become evident that it has more to do with the oral (as distinct from the laryngeal) machinery of articulate speech than any other structure.

In the diagrams (see figs. 66–71), which show the under surface of the tongue of man and other creatures more or less related to him, it is seen how remarkably this muscle has become developed since we became human. The functions accorded to it in our standard works of anatomy would apply to the needs of the dog and the pig equally to those of man; yet we see that in these animals it is a mere feeble slip of flesh which can exercise but little influence.

I have dissected it in a good many apes, among which animals it evidently had somewhat important duties quite apart from vocal production; in fact, I doubt whether in any other creature except in man we should find the tongue interfering in any way whatever in the sounds which issue from the larynx. The muscle is not only much smaller in apes than in man, but it is much more homogeneous and compact (see fig. 63); while, so far as I have been able to observe, the method of innervation shows an even greater difference than is seen in the structure of the muscle itself. To put the matter very briefly, in man the genio-glossus has become a series of a large number of independent muscular strips which are, to all intents and purposes, separate muscles, each with its little fiber of the hypoglossal nerve entering it in such a way as not to hamper its free movement, while in the apes it is apparently a single muscle, or a closely united group, acting en bloc.

It must be remembered that the adoption of an exceedingly important new method of expression and communication such as human articulate speech would require widespread and most elaborate changes in the structures which it brought into play. It is not possible on the present occasion to go into the marvelously intricate cerebral, nervous, and muscular machinery, with its innumerable bonds of coordination required for ordinary speech; but a little search into the matter will show anyone that we are here in contact with one of the most incredible marvels in nature. Most wonderful of all, the whole mechanism is, from an evolutionary standpoint, quite new—a product of merely the later fragment of a brief geological period!

When we consider the number of movements, following one another in continually varying order, required for articulate speech, it is obvious that only machinery which is able to act with every mechanical advantage and with a minimum of friction can accomplish such a task with precision. Public speakers frequently talk at the rate of 150 words a minute, while it seems possible to articulate quite clearly and correctly when speaking at the rate of 180 words a minute. If we analyze the action of the tongue when speaking at the rate of 150 words a minute, we find that there must be at least 500 different movements or adjustments. This gives 8 or 9 in every second! Such movements, it must be remembered, do not follow one another regularly in mechanical rotation like the piston-beats of a multiple-cylindered engine, but are continually varying their order. What wonder is it that coordination sometimes breaks down, with the result of a stutter or a stammer?

Now a brief examination of the intrinsic muscles of the tongue, i. e., those that begin and end in the tongue itself like the distal muscles of an elephant's trunk, will show how totally inadequate these would be to produce any such result; but immediately one takes careful note of the mode of action of the genio-glossus muscle the solution of the tongue's incredible agility becomes possible.

It is seen in the accompanying diagrams (see figs. 72–76) that the several bundles, or fasciculi, of the muscle are able to act more or less at right angles to the main plane of the tongue without anything to hamper them. For each flashlike movement of the tongue away from the palate all that is demanded is an instantaneous shortening of one or other of these independent strips. For instance, in pronouncing the letter T we place the tip of the tongue against the palate close to the upper incisor teeth (see fig. 75), and then snatch it away with great rapidity. The placing it there is probably the work of the intrinsic muscle called the superior longitudinal lingual, but the more critical action of withdrawing it at the proper moment is due to the front fibers of the genio-glossus, which become taut and braced for instantaneous action as soon as the tongue-tip is pressed against the palate.

In figure 74 it is seen that in the hard G or K exactly the same thing takes place with the central fasciculi of the muscle. A like action comes in with sounds involving L, N, R, D, J, Q; while in S, X, and all other consonants where the nice adjustment of the distance of the tongue from the palate is a matter of moment the genio-glossus muscle is capable—and appears to be the only structure capable—of exercising a quick and exact control. The same applies to the vowels, as is well shown in the accompanying diagrams after Von Meyer's drawings. Von Meyer, however, has not shown the genio-glossus muscle in action as it is shown here, and indeed, strangely enough, does not give it a word of mention as a factor in articulate speech.

It is worth while to take note of the fact that practically all the speech movements of the tongue take place in the neighborhood of its central line, and that the sides play a very subordinate part. Hence the other extrinsic muscles, such as the hypo-glossus and stylo-glossus can have little or no part in articulation. (See fig. 65.)

Now let us return to our inferior maxilla and examine the attachments and relations of the genio-glossus. It is obvious that for quick, precise movements, such as those demanded by articulate speech, it must be unhampered and have plenty of room to act. An examination of the arrangements for the play of the muscles in different animals is exceedingly instructive. In the dog, and indeed the majority of the mammalia, the tongue lies flat upon the lower jawbone, leaving practically no room for any muscular machinery. If, however, a photograph of a plaster cast of the inner surface of the wolf's jaw (see fig. 48) is compared with that of the baboon (see figs. 50, 51), which outwardly resembles it, a remarkable difference of shape is evident.

In all the monkeys—and even lower down the scale among the lemurs—we find that nature has made provision for working room for the genio-glossus muscle by excavating a kind of pit on the inner surface of the mandible beneath the tongue. This pit has been noticed by various comparative anatomists, but I had never seen any explanation of the reason why it exists, nor was I aware of its function, until a series of dissections of monkeys' jaws showed in every case the tiny tendon of the genio-glossus coming from the lower surface of the deepest part of the pit (see figs. 10, 63). The more doglike the jaw is, as in the baboons—the more, in fact, it corresponds in general outline with the prevalent type of the mandible among the lower vertebrates—the deeper is this pit. As soon, however, as the mandible begins in some degree to resemble our own, as in some chimpanzees and gibbons, and the whole lower surface becomes tilted forward, the pit seems to be no longer needed, and becomes shallower. One may as well remark in passing that it is of course obvious that originally the genio-glossus muscle had nothing whatever to do with articulate speech. The need it met in the economy of lemurs and apes was probably that of giving increased mobility to the tongue for sorting food already in the mouth. This is plainly seen when we give a monkey a nut and see him crack it and turn it about with his tongue, selecting the kernel and rejecting every fragment of shell. This ability, common among all the primates to sort food with the tongue, and with its aid to eschew unacceptable morsels, is strikingly absent in the case of most animals. Anyone can assure himself of this on seeing a dog try to get rid of some small unpalatable object. Animals, such as cattle, and especially camels and giraffes, which are liable to get dangerous thorns into their mouths, depend upon a most elaborate arrangement of the long papillæ lining their cheeks, so that by a simple backward and forward movement of the tongue such things are at length extruded.

There seems little doubt but that it is this sorting machinery of the tongue in the lower Primates which has been seized upon and greatly elaborated for the new and wondrous mechanism of articulate speech.

Before going further it may be as well to clear up another point which seems to have puzzled some of my audience when I was lecturing at Birmingham. The question was asked me, "How is a parrot able to talk if he has no chin?" An equally pertinent question would be, "How is a phonograph able to talk when it possesses no chin?" A parrot has deep down behind its breastbone a marvelously elaborate and versatile sound-producing apparatus, almost as different from any possessed by ourselves as is the mechanism of a phonograph. When man began to speak, he had to make use of raw material, which was there already, to build up his talking machinery. That the parrot and the phonograph can speak, merely proves that there are other ways of doing it; but the only question which we here have to discuss is how man did it himself with such means as were at his disposal.

When we come to examine the difference between prehistoric man and modern savages we find the same order of structural change in the mandible still going on, tending to the greater efficiency of the genio-glossus muscle for speaking purposes. When this fanlike group of muscular fibers came out of a deep pit, such as is seen in the illustration of the jaws of the lower monkeys, the fibers were obviously hampered by being bunched and huddled together. (See fig. 63.) As the jaw became tilted forward, giving more engine room beneath the tongue, the need for the pit became less, and it becomes shallower and shallower until we find it a mere depression, as in the Siamang gibbon. (See fig. 12.) These changes are plainly shown in the series of plaster casts of which photographs are reproduced in figures 9 to 18. First of all is a fossil lemur, in which the jaw still retains its generalized character, but is beginning to show depressions as the genial pit makes its appearance; then one has apes like the baboons, macaques, or colobus monkeys, with an exceedingly deep pit or depression. Next come anthropoids, in which the lower edge of the jaw is already being dropped into something resembling a chin, and the depression at once becomes less apparent. Next are some jawbones of prehistoric man, namely, the Heidelberg and the Naulette jaws, in which the depression is still plainly seen and is scarcely less marked than in the gibbon.

It will be seen that the Heidelberg jaw shows on its surface a tubercle; indeed, I understand that one of the descriptions of it published soon after it was found stated that it did not differ from modern jaws in this respect. (See fig. 41.) A brief comparison with the other casts, however, will make it plain that the tubercle here seen is too low down to be that for the genio-glossus, and is plainly the one for the genio-hyoid muscle mentioned in the earlier part of this article, which has nothing whatever to do with the tongue. This tubercle is quite common among the apes.

When we come to the Pygmies and Bushmen we find in the majority of jaws the remains of this pit or a mere flat surface; but in some African dwarf races, and among the Hottentots, Veddas, and Andamanese, two little prominences are seen beginning to grow at the lower edge of the pit. (See figs. 19–29.) These tubercles, as we pass to higher and more civilized races, become more and more prominent, until we get the European type familiar to all students of anatomy.

Now the bearing of these changes on the functions of the genio-glossus muscle is fairly evident. First of all, it needed a deep pit in the lower apes to get room to work at all. Then the depth of the pit became unnecessary through the tilting of the lower surface of the mandible; and by means of this change the muscle was obviously given greater freedom for action. Then we get a nearly flat surface; and finally a prominence appears, enabling the separate fasciculi of the muscle to spread from the very point of origin and so act independently without hampering their neighbors. (See figs. 18, 32, 38, 42.)

We are thus able to follow the whole course of the history of the genio-glossus muscle from fossil lemurs to modern men, and a very remarkable history it is; difficult, I believe, to parallel in any other structure of the body which we may pick out for the purpose. We found it in the lower apes, in which it first appears as an important factor in tongue movements, coming out of a hole in the lower jaw, and we take leave of it mounted upon a pinnacle quite as high as the pit was deep. (See figs. 63, 64.) This is as if an organism commenced its career in the uttermost depths of the sea, and attained its full development at the top of Mount Everest! The muscle might stand above all things else in our bodies as a symbol and sign of our upward progress. For I think it can not be denied that its development marched *pari passu* with the development of intellectual capacities and the increasing need of a means of clear expression.

When speech began, as distinct from mere animal stereotyped cries and other noises, it is, of course, impossible to say. For the speech of certain low savages, consisting of grunts, guttural sounds, and clicks, it is fairly obvious that few tongue movements are necessary; but wherever languages have become more elaborate—and many of them in different parts of the world appear to have had an independent origin from more brutelike utterances—we find that the genioglossus muscle comes more and more into play, as is evidenced by its tubercles of attachment and by the forward tilt of the chin to give elbow room among all the higher races.

The speech of monkeys is, of course, a myth, and most of our anthropoid friends are curiously silent beings. The two exceptions appear to be the chimpanzee, which is described by travelers as shouting and calling in varied tones in the forest, and certain gibbons, which appear to come nearer to us in the variety of articulate utterances than any other of the Primates. From the series of plaster casts shown in the plates, and in many others that are in my possession it seems to become evident that, speaking generally, the genial tubercles may be taken as some index of social and intellectual development. They are not, of course, strictly necessary for speech, but it is clear, both from anatomical and general reasons, that they greatly facilitate speech.

It is interesting to watch their development in the normal human subject (see figs. 30–32), and I have several casts which illustrate this fairly clearly. In all young children they are absent, and up to the age of 14 years they make but a small show; in fact, the jaw of a child of 14 years almost exactly resembles in this respect that of a Bushman or Pygmy; between 14 and 17, however, they appear to obtain their full development. How far that development is dependent upon the use of the muscle it is difficult to say; my own belief is that, like many of the roughnesses and ridges upon our bones, they are very largely the product of vigorous muscular action, i. e., nature has met the obvious need of the muscle by altering the bone in a certain specific direction.

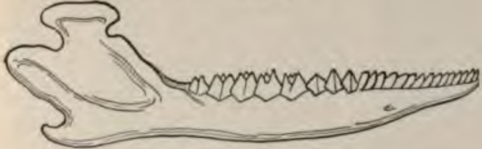
For many years I have been endeavoring to get evidence as to the presence or absence of the tubercles in deaf mutes. Such as I have, so far as it goes, seems to show that in adults who have never acquired articulate speech they are quite absent. (See fig. 17.) In the one specimen I have from a deaf mute, the bone almost exactly resembles that of a Bushman, or a child of 14.

A glance over the peculiarities of the tubercles in the accompanying plates shows how extraordinarily variable they are in different individuals and in different races (see figs. 34, 35), but before any safe generalized conclusions are drawn from these diversities one ought to have many thousands before one for comparison. It seems to me quite probable that this would prove a fruitful line of research for anyone with leisure and opportunity to follow up; for, when we consider the distinct anatomical problems involved in the pronouncing of different languages it seems not improbable that definite structural peculiarities might become apparent in accordance with the tongue spoken. We know that it is practically impossible for Europeans to acquire the elaborate tongue and throat movements of not a few barbarous languages, and it would be extraordinary indeed if this wide diversity in muscular function did not leave some trace which the methods of the anatomist might reveal.

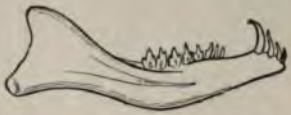
In figure 42 is reproduced a photograph of a cast from part of the jawbone of O'Brien, the Irish giant, the capture of whose body gave John Hunter so much trouble. I placed it there, because it shows the typical arrangement of the genial tubercles in a very marked manner. It also tells us something else, which I think is not a little instructive. There can be no question that the Irish speak our language with much greater correctness and precision than the average Anglo-Saxon, and further investigations seemed to show that in Irish jaws there was a fuller development of the genial tubercles than in those found in English museums. On following the same line of research a little further it became apparent that a greater symmetry and uniformity of the development of the genial tubercles was to be found in French and Italian jaws than in English. This seems to be a matter well worth following up.

A few other suggestive points come out from a further examination of the plaster casts, reproduced in the plates, which have no very direct bearing upon our present inquiry. One, for instance, is the obvious kinship between certain American monkeys and the lemurs, as evidenced by the duplicated pit. (See figs. 52, 53.) In nearly all the Old World apes of which I have specimens the two cavities appear in close proximity or merged into one, but in the American monkeys and the Madagascar lemurs they are generally separated by a marked interval. The lower jaw in certain highly specialized apes such as the howler and proboscis monkeys, appears very difficult to interpret. Here again a more extended collection, giving opportunities for exact comparative methods, would be certain to throw a good deal of light on what is at present a subject which seems to have been very little studied.

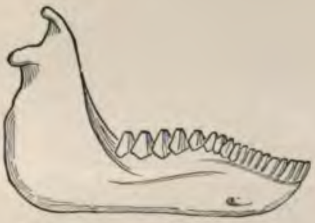
Apart from these by-products of the inquiry I think it will be acknowledged that many of the facts put forward in this article go far in justifying my suggestion that the chin, which is so marked a characteristic of the modern human mandible, may be considered part of the necessary mechanism of articulate speech.



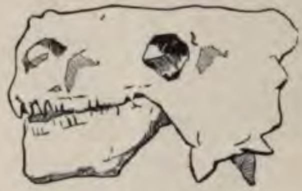
1. *Amphitherium oweni* (Stonesfield State).



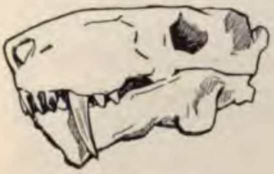
2. Dromatherium (Upper Trias, North Carolina).



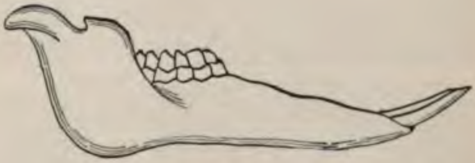
3. Arsinotherium (Eocene).



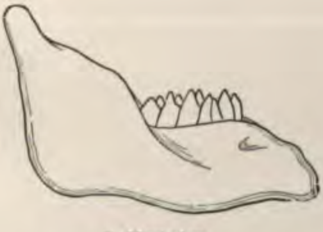
4. Pariasaurus.



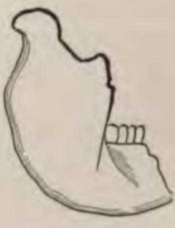
5. Inostransevia.



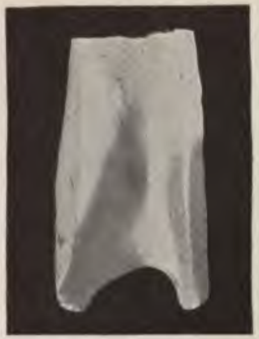
6. Tetrabelodon.



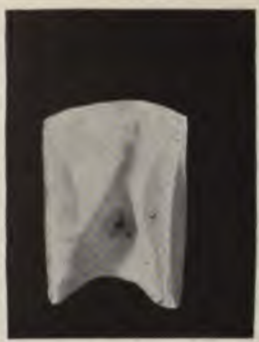
7. Mastodon.



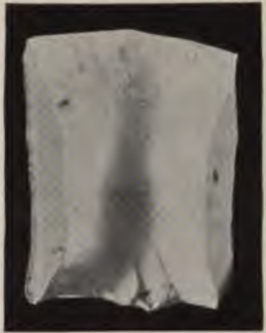
8. *Elephas primigenius.*



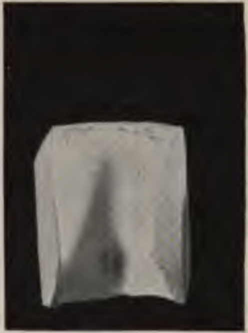
9. Fossil Lemur.



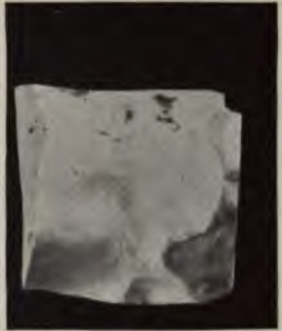
10. Macaque monkey.



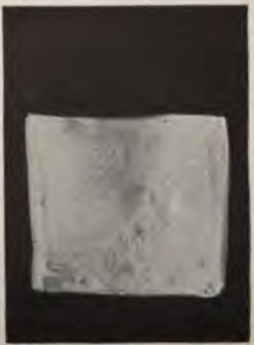
11. Chimpanzee (young male).



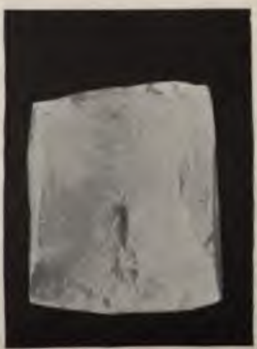
12. Siamang gibbon.



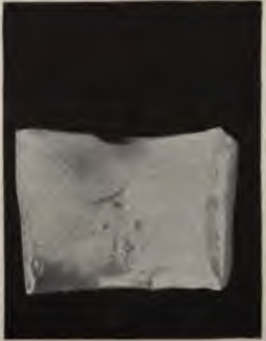
13. The Naulette jaw (Spy type).



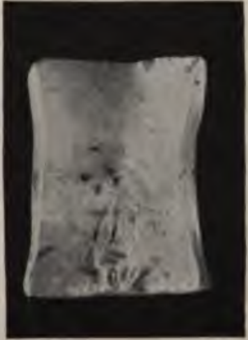
14. Akka pygmy, from Central Africa.



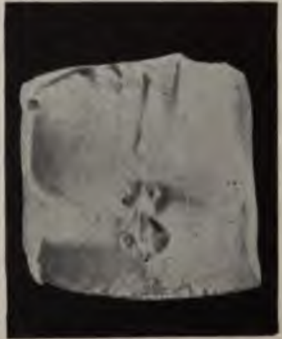
15. Bushman.



16. Hottentot.



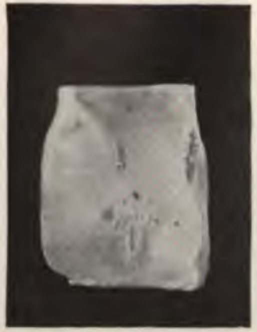
17. Deaf mute (French).



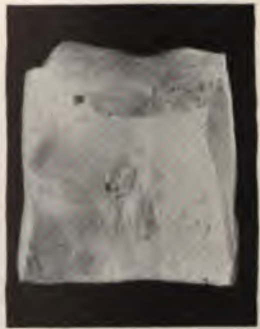
18. An ordinary European type.

Figs. 9-18 show the progressive stages from the beginning of the genial pit in the lemur to the fully developed genial tubercles in modern civilized man.

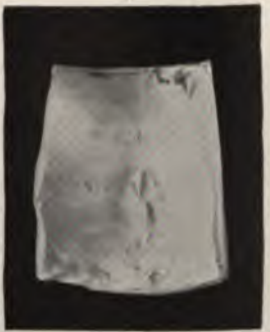
CASTS OF THE INSIDES OF LOWER JAWS.



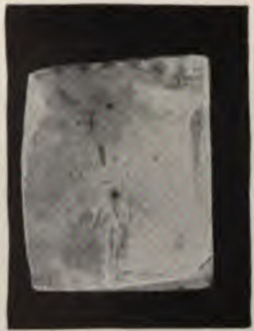
19. Hottentot.



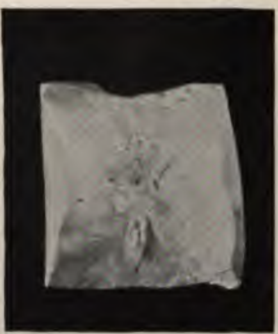
20. Hottentot.



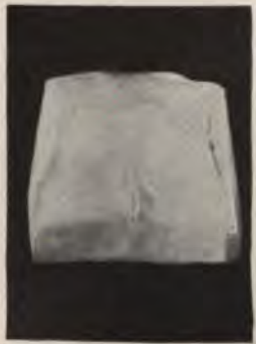
21. Bushman.



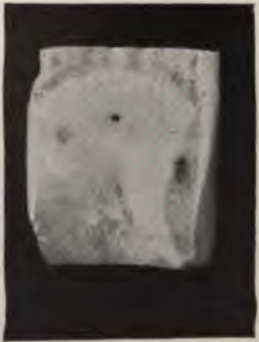
22. Hottentot.



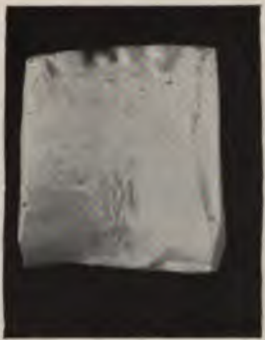
23. Bushman.



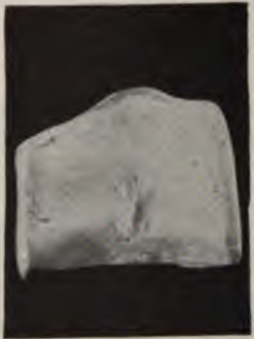
24. Hottentot.



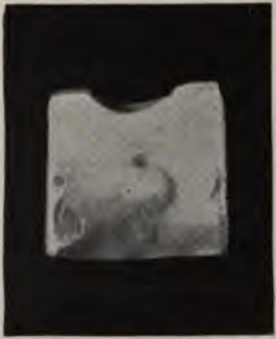
25. Bushman.



26. Andaman Islander (Negrito).



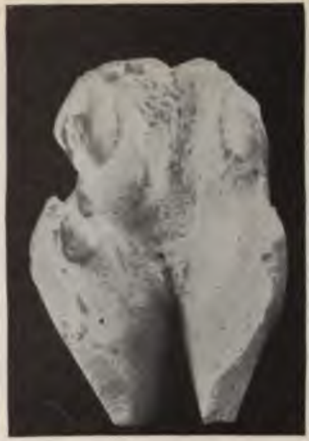
27. Veddah (Ceylon).



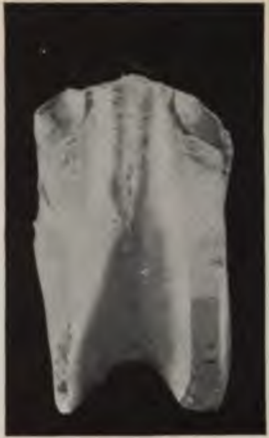
28. Low type (West Africa).

Figs. 19-28 show the imperfect development of genial tubercle and the persistence of the "simian pit" among certain low races with only imperfect articulate speech.

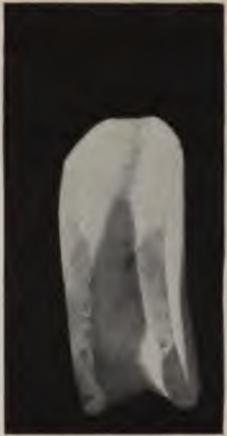
CASTS OF THE INSIDES OF LOWER JAWS.



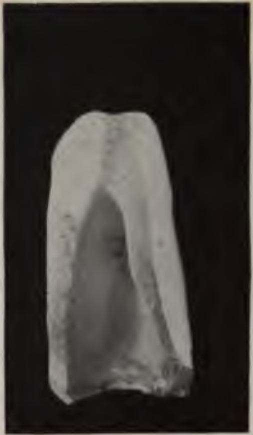
48. Wolf.



49. Leopard.

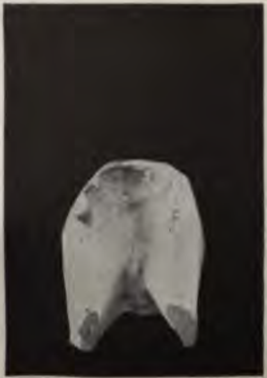


50. Chacma baboon.

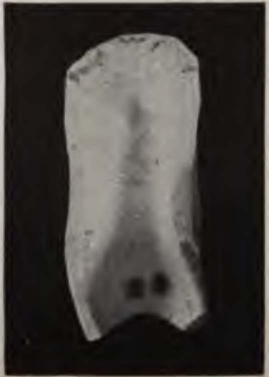


51. Anubis baboon.

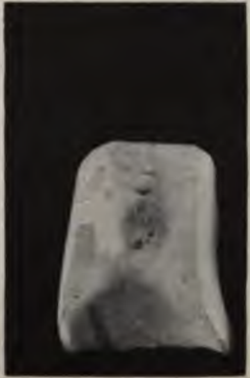
Figs. 48–51 show the marked contrast on the inner side of the jaw between the doglike apes and the Canidae and Felidae.



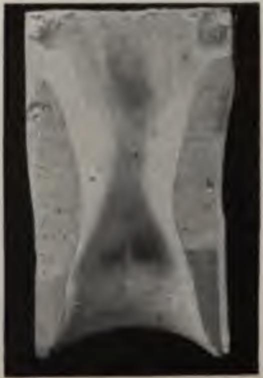
52. Lemur.



53. Howler monkey.



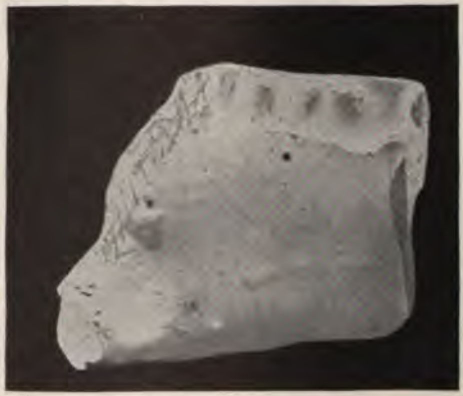
54. Proboscis monkey.



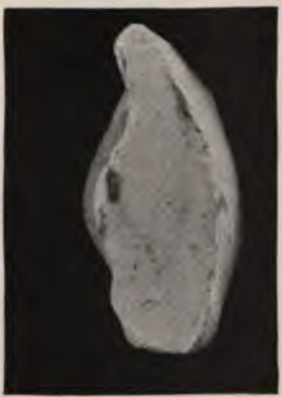
55. Chimpanzee with exceptional pit.

Figs. 52–55 form an extremely heterogeneous group.

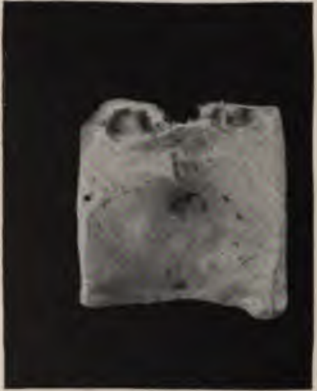
CASTS OF THE INSIDES OF LOWER JAWS.



56. The Piltdown jaw.



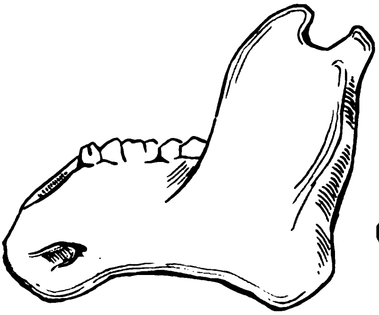
57. Profile section of the Heidelberg jaw.



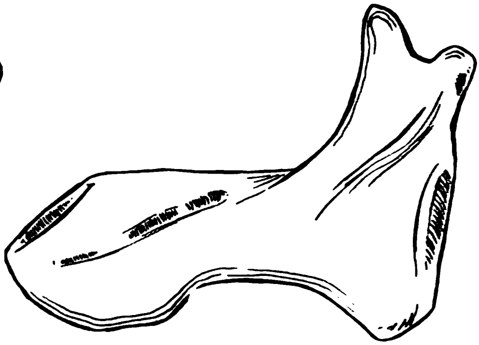
58. Central African pigmy.

Figs. 56–58 show prehistoric jaws compared with a low type of modern savage.

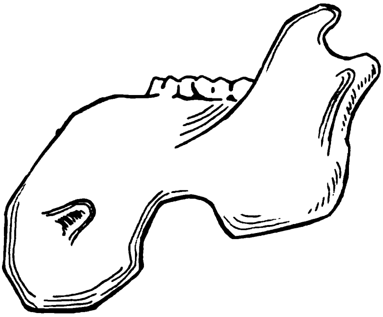
CASTS OF THE INSIDES OF LOWER JAWS.



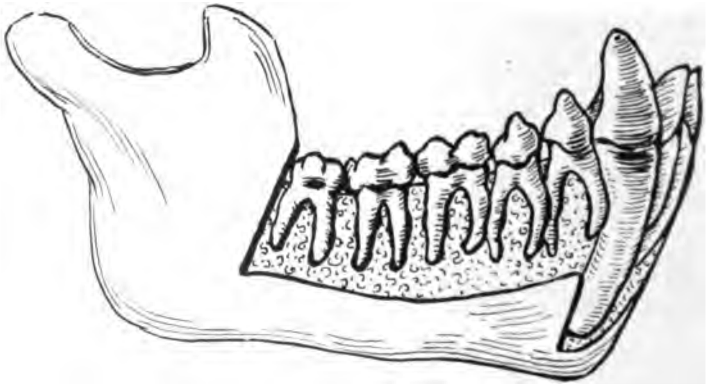
59. Halitherium.



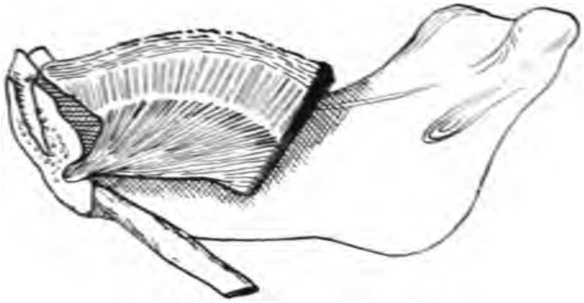
60. Steller's sea cow.



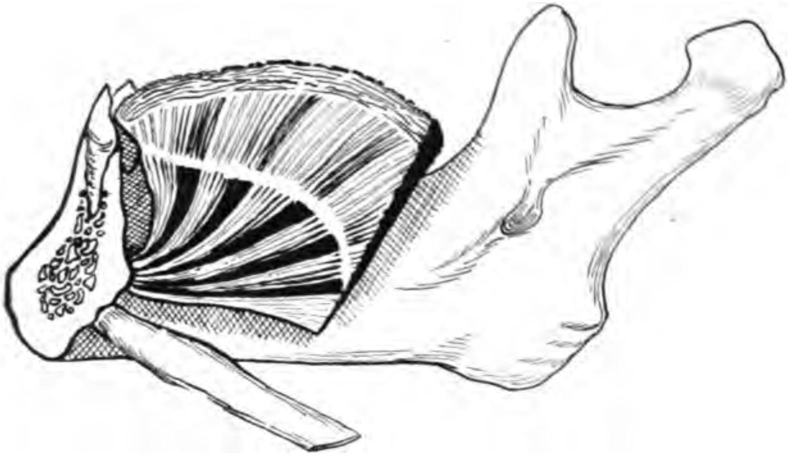
61. Dugong.



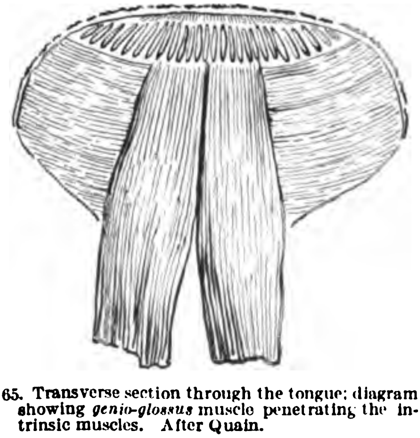
62. The jawbone of a chimpanzee, showing roots of teeth and the stout buttressed socket of the canine filling the side of the "chin."



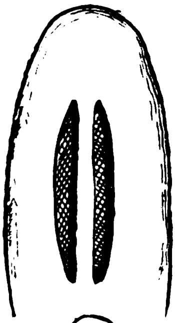
63. The lower jaw and tongue of a macaque, from a drawing of a dissection by the author, showing the deep pit for the origin of the *genio-glossus* muscle.



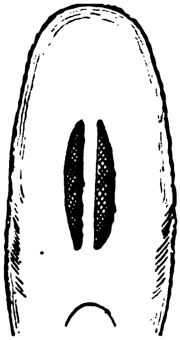
64. Human jawbone with part of the tongue, drawing showing the spreading *fasciculi* of the *genio-glossus* muscle, and their origin from the upper genial tubercle.



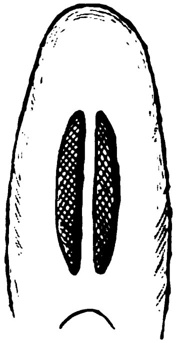
65. Transverse section through the tongue; diagram showing *genio-glossus* muscle penetrating the intrinsic muscles. After Quain.



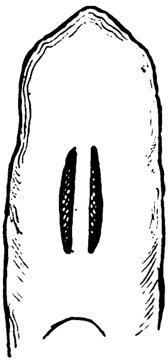
66. Siamang.



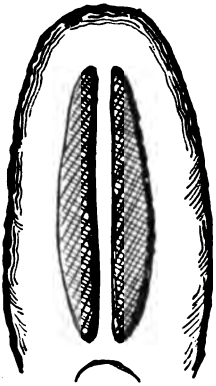
67. Orang.



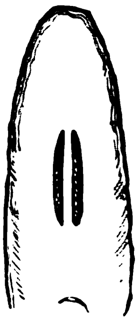
68. Chimpanzee.



69. Dog.

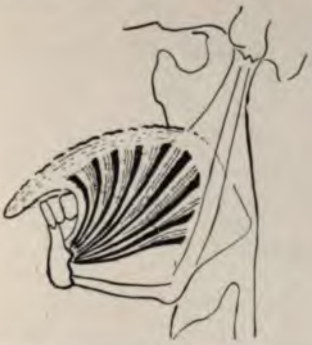


70. Man.

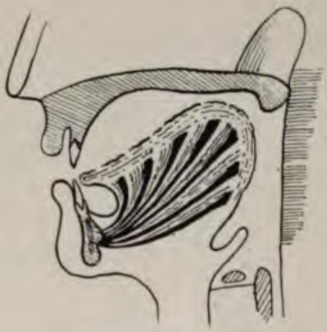


71. Pig.

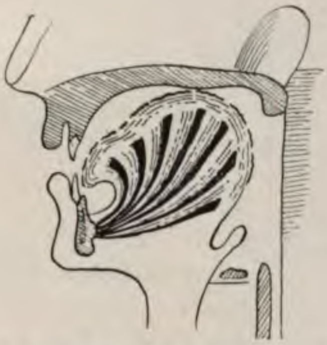
Figs. 66–71 show the under surface of the tongue and the proportions of the *genio-glossus* muscle.



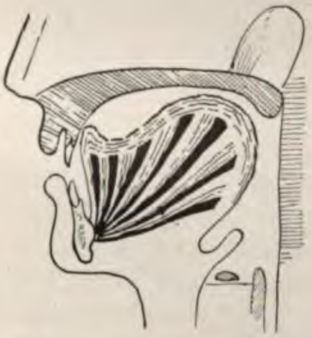
72. Diagram of the *genio-glossus* muscle at rest.



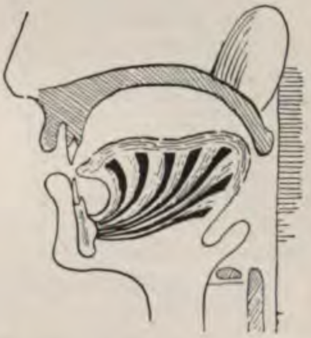
73. Diagram of the *genio-glossus* muscle in pronouncing the sound "Oo."



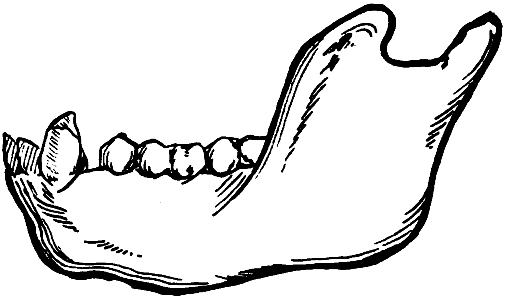
74. Diagram of the *genio-glossus* muscle in pronouncing the letter "K."



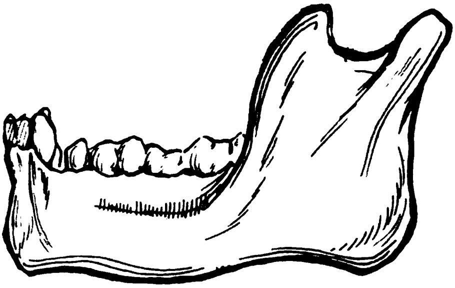
75. Diagram of the *genio-glossus* muscle in pronouncing the letter "T."



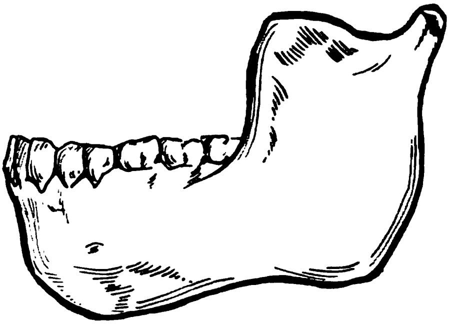
76. Diagram of the *genio-glossus* muscle in pronouncing the sound "Ah."



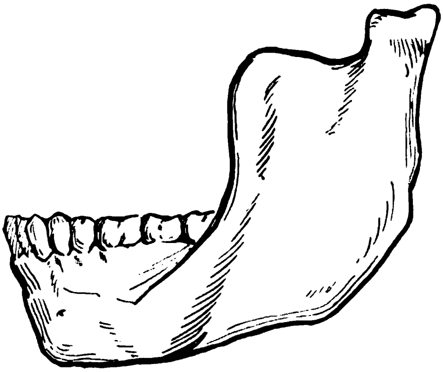
77. Chimpanzee.



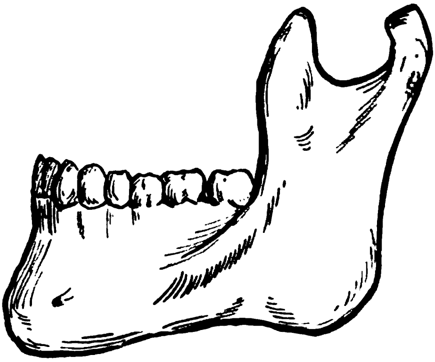
78. Siamang.



79. Heidelberg.



80. Neander type.



81. Modern man.

RECENT DEVELOPMENTS IN THE ART OF ILLUMINATION.[1]

By Preston S. Millar,
Electrical Testing Laboratories, New York, N. Y.

[With 3 plates.]

In the Journal of the Franklin Institute for the last few years there are to be found a number of papers dealing with certain phases of illumination. These are of especial interest to a limited number of institute members, but most of them are somewhat esoteric and presumably have been read in detail by but a limited number of institute members. Consideration of the character of the institute membership has led the writer to feel that he could perhaps be of some service by endeavoring to outline in a comprehensive way the nature and scope of the art of illumination and by making available a brief review of developments in illumination which will place before the members a general view of the subject in its large features. Accordingly, this paper will be found to contain but little of new interest for the illuminating engineer, being written more especially for the consideration of the membership of the institute at large.

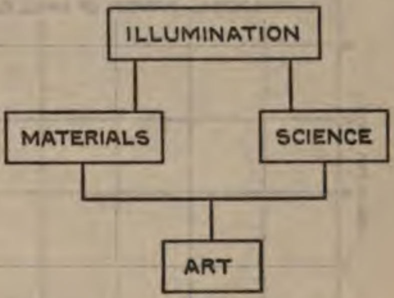


Fig. 1.

In the discussion which follows a fragmentary bibliography is included. The references which are noted are intended to direct attention to significant papers, and to furnish an indication of the manner in which the several phases of each division of the subject of illumination are being developed.

Illuminating engineering as a distinct specialty is perhaps not generally understood. The name illuminating engineering as applied to this specialty is perhaps not wisely chosen. It will serve, however, for the purpose of this discussion. Illuminating engineering, then, as a specialty may be represented by the diagram in figure 1.

The specialist applies the materials of illumination with the aid of the science of illumination, and practices the art of illumination.

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[1] Presented at a joint meeting of the Electrical Section and the Illuminating Engineering Society, held Thursday, Apr. 9, 1914. (Reprinted by permission from the Journal of the Franklin Institute, October, 1914.)

THE MATERIALS OF ILLUMINATION.

The materials of illumination may be classified as illuminants—natural and artificial—lighting auxiliaries, and fixtures (fig. 2).

Considering first incandescent electric lamps,[1] it may be noted that increases in the efficiency of light production have been accompanied by increase in the variety of illuminants both as to types and sizes. Neglecting for the moment other qualities than the efficiency of light production, your attention is directed to the diagram in figure 3. This shows improvements in incandescent electric lamps which were made available some years ago and the status of lamps of more recent development. It will be noted that the advances in the efficiency of light production have been marked. The carbon filament lamp which had remained without material efficiency improvement from 1893 to 1905 was at that time improved through the development of the so-called "metallized" carbon filament, and in that form remains the most efficient type of carbon filament incandescent lamp. The carbon filament lamp had been the standard form for general electric lighting, and continued to be the standard lamp and the most largely produced lamp until about 1912. Its preeminence was challenged before that time because of the adoption of the metallized carbon

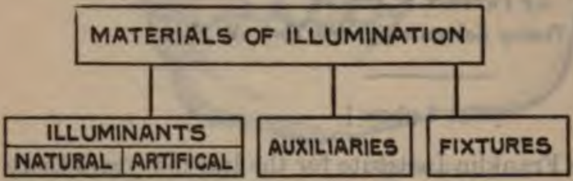

FIG. 2.

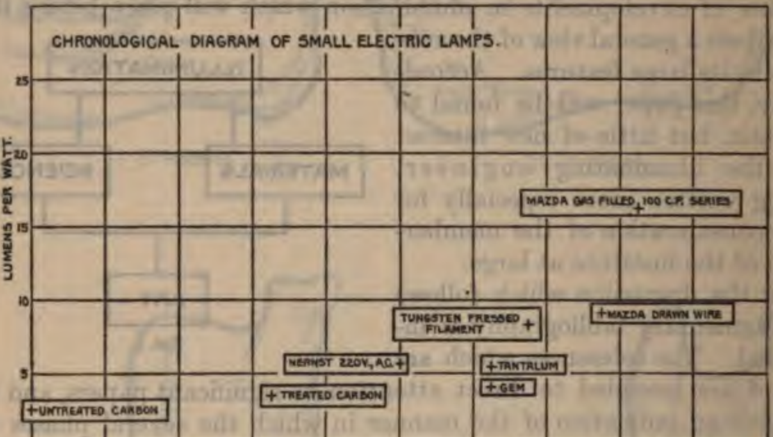

FIG. 3.

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[1] Incandescent lamps: "A new carbon filament," Howell; Trans. A. I. E. E., 1905, p. 839. "New types of incandescent lamps," Sharp; Trans. A. I. E. E., 1906, p. 815. "High efficiency lamps," Doane; Proceedings N. E. L. A., 1910. "Recent progress in the art of lamp making," Randall; N. E. L. A., 1913. "*Tungsten lam* [illegible] fficiency," Langmuir and Orange; Trans. A. I. E. E., 1913, p. 1915.

filament lamp for free renewal to customers by the larger central stations of the country, and was lost in 1912 as a result of the influence of lamp manufacturers in promoting the sale of the metallized filament rather than the sale of the carbon filament lamp. The substitution of the metallized carbon filament lamp for the earlier form of carbon filament lamp resulted in an increase of the standard of illumination throughout the country, for it consumed the same energy and produced about 20 per cent more light than did the earlier carbon filament lamp.

In 1905 the various forms of carbon filament lamps were supplemented by the tantalum lamp, an importation from Europe. This lamp never entered largely into American practice, its largest sale in the country probably never exceeding 3 per cent of the total sales of incandescent lamps. Its inferiority when operated upon alternating current and the announcement of the invention of the tungsten lamp shortly after its appearance prevented its attaining a position of importance in our practice.

The tungsten filament lamp, first made available commercially in 1907, was a marked improvement over other lamps then available, although its fragility and relatively high price led to restriction of its use in the earlier years of its history. Through the splendid development work of American lamp manufacturers this lamp has been rendered much more effective in all respects than it was a few years ago. The substitution of the drawn wire mounted as a continuous filament placed the lamp in a class with the carbon filament lamp in respect to ruggedness. The development of bulb-blackening preventives has permitted its operation at somewhat higher efficiencies. These improvements, with notable price reductions, have led to the large use of the tungsten, now known chiefly as the Mazda lamp, so that in 1913 sales of the Mazda lamp exceeded sales of all other types of incandescent electric lamps, notwithstanding the fact that the life standard which it sets is twice that which obtained previously.

During the past year a new form of tungsten filament lamp has been announced, in which the bulb contains an inert gas which reduces the rate of evaporation of the filament and permits operation of the lamp at a higher efficiency. This gas-filled Mazda lamp is chiefly of importance in the larger sizes, and in effect creates a new lamp of characteristics similar to the incandescent lamp but of power equivalent to the arc lamp. In its smaller sizes it is included on the diagram, marking the highest efficiency attainment in the production of light by small incandescent lamps.

The Nernst lamp was brought to its highest development in 1908 in the Westinghouse Nernst. Its active exploitation practically ceased in 1912, due to the superior qualities of the tungsten filament lamps.

Paralleling the improvement in efficiency of light production by means of incandescent lamps have come improvements in larger electric illuminants.[1] The pure carbon open arc lamp was supplemented in about 1893 by the inclosed carbon lamp, which largely supplanted it in spite of a lower efficiency because of more desirable operating characteristics. This inclosed carbon arc lamp has been for a number of years the standard street lighting illuminant of America, and only within the past two or three years has yielded its position of preeminence in that field to the newer and superior forms of arc lamps. The intensified carbon arc lamp has found considerable application in the lighting of interiors, principally stores. In this lamp pure carbons of relatively small diameter are operated at high current density within a globe which partially restricts the air supply. The resultant light is more nearly white than that usually obtained from the carbon arc lamp and offers some advantages for store lighting purposes.

The metallic electrode arc lamp, of which the magnetite and metallic flame lamps are the principal examples, has come into large use in street lighting and more than any other type of lamp has supplanted the inclosed carbon arc lamp. This lamp differs radically from earlier forms of arc lamps in that the light is produced by luminescence and emanates wholly from the arc stream, whereas in the several forms of pure carbon arc lamps the light is produced by incandescence of the electrode ends.

The flame arc lamp (short-life form) is the highest achievement in efficiency of light production among commercial electric illuminants. In its earlier forms it suffered from short electrode life, which made its operation costly and practically limited its usefulness in this country to display lighting. In repetition of the history of the pure carbon arc lamp, the flame arc lamp, which is equipped with carbons impregnated with various salts, has been adapted to secure long electrode life by partially inclosing the arc and employing large diameter electrodes. As in the earlier lamp, this operating advantage has been secured at the expense of loss in efficiency, and the long-burning flame arc lamp is not to be confused with the more efficient short-life flame arc lamp in this respect.

The gas-filled Mazda lamp,[2] small sizes of which have been included in consideration of incandescent lamps, has not yet emerged from the developmental stage, but is known to be among the very highest efficiency electric illuminants, especially in its larger sizes.

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[1] Arc lamps: "The invention of the inclosed arc lamp," Marks, The Sibley Journal of Engineering, October, 1907. "Properties and industrial applications of the flame arc lamp," Blondel, International Electrical Congress, 1904, vol. 2, p. 729. "The electric arc," Steinmetz, International Electrical Congress vol. 2, p. 710. "The metallic flame arc lamp," Stephens, Trans. Illg. Eng. Soc., 1907, p. 657. "Design of luminous arc lamps," Halvorson, General Elec. Review, 1911, p. 578. "Arc lighting," Steinmetz, General Elec. Review, 1911, p. 568. "Ornamental luminous arc lighting at New Haven," Halvorson, General Elec. Review, 1912, p. 220. "Inclosed flame arc lamp," Chamberlain, General Elec. Review, 1912, p. 706.

[2] Mazda gas-filled lamps: "Tungsten lamps of high frequency," Langmuir and Orange, Trans. A. I. E. E., 1913, p. 1915.

The mercury arc lamp is available in two types. The low-pressure arc in glass tubes is the earlier form and is in more general use than the high-pressure quartz tube lamp. The latter, however, surpasses it in efficiency.[1]

The Moore tube, filled with nitrogen for general illumination purposes, has been used to a limited extent for special classes of lighting. Smaller sizes in which carbon dioxide replaces nitrogen are used only as artificial daylight.

The Neon tube, as devised by Claude of France, marks a distinct advance in the efficiency of tube lighting. Whereas the Moore nitrogen-filled tube yields light of a pinkish-yellow tinge, the Neon tube gives light which is red.[2]

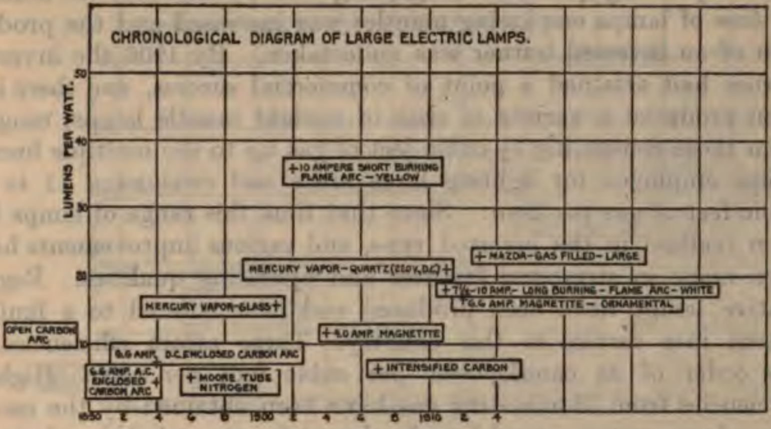

FIG. 4.

The diagram, figure 4, summarizes and compares the light-producing efficiency of these several large illuminants. The inclosed carbon arc lamps and the Moore tube are the lowest in efficiency. The 4-ampere magnetite lamp is of substantially the same efficiency as the old open carbon arc lamp. The 6.6-ampere magnetite and the low-pressure mercury vapor lamp are next in order, just failing to reach the efficiency of the long-burning flame arc lamp, of the quartz high-pressure mercury vapor lamp, and the Mazda gas-filled lamp. A short-burning flame arc lamp producing 36 lumens per watt is distinctly the most efficient of these large illuminants.

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[1] Mercury vapor lamps: "Notes on the Cooper-Hewitt lamp," Cooper-Hewitt, Elec. World and Engineer, 1910, p. 679.

[2] Tube lighting: "Light from gaseous conductors within glass tubes," Moore, Trans. A. I. E. E., 1907, p. 605. "Neon tube lighting," Claude, Trans. Illg. Eng. Soc., 1913, p. 371.

The development of the gas mantle by Von Welsbach, in 1884, was the beginning of a new era in gas lighting.[1] When the mantle burner was introduced there were available the flat-flame burner, producing 1 to 2 candlepower per cubic foot of 16-candlepower coal gas; the Argand burner, producing perhaps 3 candlepower per cubic foot; the regenerative burners, producing as much as 7 to 10 candlepower. The Welsbach lamp made available at first 10 and, later, something like 15 candlepower per cubic foot of gas. Since the early developments of the modern Welsbach lamp in, say, 1891, no material improvements have been made in the efficiency of light production from small mantle burners, though burners, mantles, and auxiliaries have been further developed along lines which make for better operating qualities. Beginning with about 1901, the number of sizes of lamps employing mantles was increased and the production of an inverted burner was undertaken. By 1906 the inverted burner had attained a point of commercial success, and there had been produced a variety of sizes of upright mantle lamps, ranging from those consuming 1¼ cubic feet of gas up to the multiple burner lamps employed for lighting large areas and consuming 12 to 18 cubic feet of gas per hour. Since that time this range of lamps has been realized in the inverted type, and various improvements have been made in structural features and operating qualities. Regenerative lamps have been produced and have entered to a limited extent into service in this country. These attain efficiencies of the order of 28 candlepower per cubic foot per hour. Highest efficiencies from illuminating gas have been obtained by the use of pressed gas systems, used largely abroad for street lighting, but not as yet introduced extensively in this country. These yield light-producing efficiencies of the order of 35 candlepower per cubic foot per hour.

The progress in efficiency of light production indicated by the record of the manufacturer of gas illuminants is shown in figure 5.

Among other illuminants[2] the kerosene oil lamp is, of course, the most important. Its earlier form was improved by the substitution of a round-wick, center-draft lamp for the flat-wick burner. The incandescent mantle has been applied to the kerosene lamp, but without such success as to command general substitution in oil-lamp lighting. Acetylene lighting, filling a limited part of the general illumination field, is not understood to be making any considerable advance in efficiency of light production. The same is true of gasoline lighting.

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[1] Gas lamps: "Inverted gas lighting;" Whitaker; Trans. Illg. Eng. Soc., 1907, p. 764. "Modern gas lighting conveniences;" Litle; Trans. Illg. Eng. Soc., 1908, p. 418. "Symposium on Ligh-pressure gas lighting;" Goodenough, Klatte and Zeek; Trans. Illg. Eng. Soc., 1912, p. 506.

[2] Miscellaneous illuminants: "The progress of the gas industry;" Morrison; Trans. Illg. Eng. Soc., 1909, p. 36.

One illuminant has been produced which yields light of a color closely approximating what may be considered to be average daylight. That is the Moore carbon-dioxide tube. Mazda lamps, the intensified carbon arc lamp, and gas mantle lamps have been equipped with color screens intended to modify the light to produce artificial daylight.[1] Some of these duplications of natural light are excellent and are being employed with good effect for commercial purposes. Other illuminants or equipments for illuminants have been announced as the equivalent of daylight or as having daylight qualities. Unfortunately, however, there has been much misrepresentation connected with this, and so far as the writer is aware, only the efforts named above should be regarded seriously in this connection.

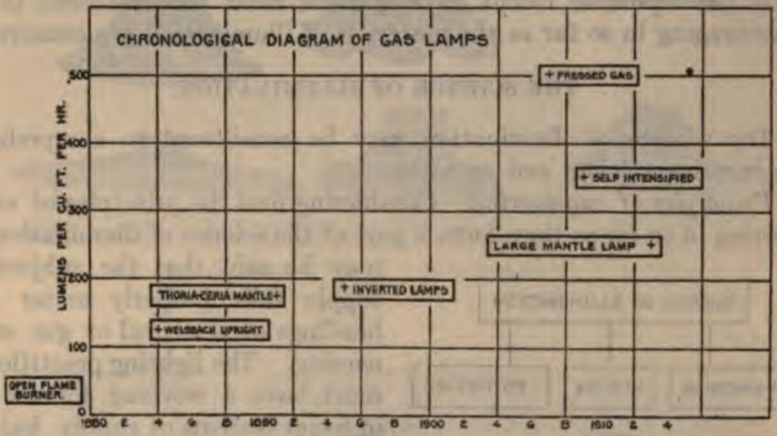

FIG. 5.

Lighting auxiliaries,[2] including reflectors, globes, shades, etc., have been greatly improved in recent years. Plate 1, figure 1, illustrates some types of reflectors typical of those which were sold 10 to 15 years ago. Plate 1, figure 2, shows an assortment of modern reflectors which surpass those previously available in appearance, and in that they conceal the light source and diffuse the light. They excel also in efficiency of light redirection.

The design and manufacture of fixtures [3] may be divided into two classes; namely, fixtures of distinctive design and stock fixtures. The former can not well be generalized; the latter, which, of course, are more largely used, have been improved somewhat with the improvement in taste in regard to design which is gradually being wrought among the public at large. At least, it may be said, that the atrocious fixtures which were placed in moderate priced houses 20 years or so ago are now supplanted by more tasteful fixtures.

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[1] Artificial daylight illuminants: "A standard for color values—The white Moore light," Moore; Trans. Illg. Eng. Soc., 1910, p. 209. "A lamp for artificial daylight;" Hussey; Trans. Illg. Eng. Soc., 1912, p. 73. "Subtractive production of artificial daylight;" Ives and Luckiesch; Electrical World, 1911, p. 1092. "A gas artificial daylight;" Ives and Brady; Lighting Journal, 1913, p. 131.

[2] Auxiliaries: "The principles of shades and reflectors;" Bell; Trans. Illg. Eng. Soc., 1909, p. 723. "Scientific principles of globes and reflectors;" Lansingh; Trans. Illg. Eng. Soc., 1910, p. 49. "Symposium on illuminating glassware;" Jones, Marshall, Young, and Hibben; Trans. Illg. Eng. Soc., 1911, p. 854.

[3] Fixtures: "Fixture design," Lansingh and Heck; Trans. Illg. Eng. Soc., 1907, pp. 728-784. "The relation of fixture design to modern illuminating practice" Hopton and Watkins; Trans. Illg. Eng. Soc. 1910, p 310.

Plate 2, figure 1, shows a cluster of electric lamps which is typical of those sold 10 years ago. Contrast them with the view in plate 2, figure 2, of modern fixtures designed for the same class of use. The latter are superior in almost every respect and, while possibly more costly, yield a much better service return upon the investment.

It is thus apparent that progress in recent years in the design and construction of materials of illumination has been rapid, and that the report of recent developments must be considered to be encouraging in so far as the materials of illumination are concerned.

THE SCIENCE OF ILLUMINATION.

The science of illumination may be considered to comprehend engineering, vision, and esthetics.

Principles of engineering.—Considering first the principles of engineering in so far as they form a part of the science of illumination, it may be said that the subject of supply falls properly under the headings of electrical or gas engineering. The lighting practitioner must have a working knowledge of usual systems of supply, but no special knowledge is essential.

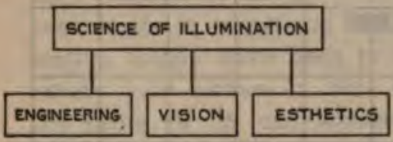

FIG. 6.

In the matter of installation[1] the practitioner needs to be somewhat more skilled. The electrical contractor, plumber, etc., are prepared to handle installations effectively, but are in need of guidance of the illuminating expert; hence, the latter requires a good working knowledge of the subject.

A thorough knowledge of the design, construction, lighting qualities, and operating characteristics of artificial illuminants is essential, and this subject has not been neglected in the literature of the art. Daylight[2] also has been studied as to direction, diffusion, intensity, color, etc. Very complete information regarding sources of illumination is thus available to the practitioner.

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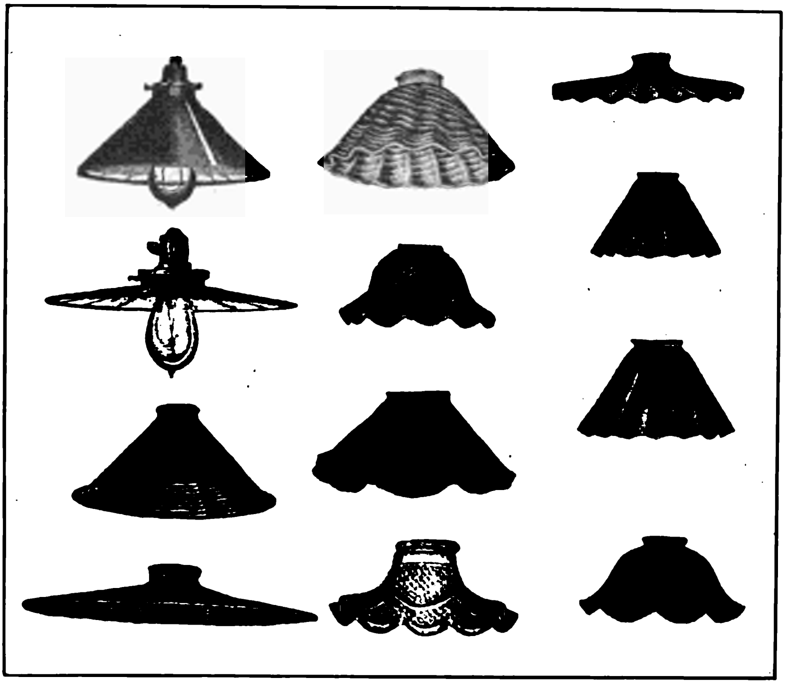
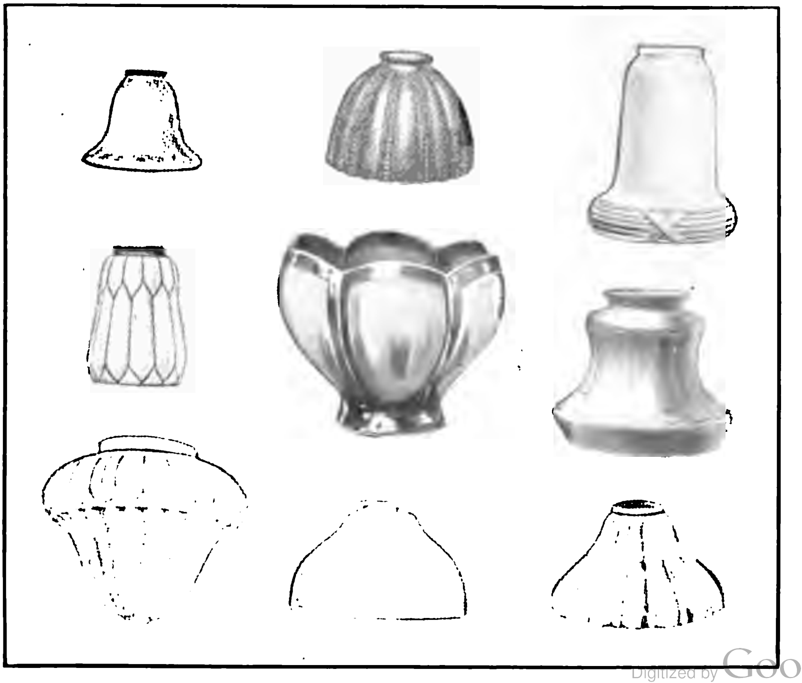
[1] Operating characteristics of illuminants: "Deterioration of gas lighting units in service;" Pierce; Trans. Illg. Eng. Soc., 1912, p. 677. "The relation of the incandescent lamp to the lighting service;" Cooper and Campbell; National Elec. Light Assn., 1913, p. 400. "The proper lamp for a circuit;" Campbell and Cooper; N. E. L. A., 1912, vol. 3, p. 338.

[2] Daylight: "Daylight illumination;" Marsh; Trans. Illg. Eng. Soc., 1908, p. 224. "The intensity of natural illumination throughout the day;" Lewinson; Trans. Illg. Eng. Soc., 1908, p. 482. "The distribution of luminosity in nature;" Trans. Illg. Eng. Soc., 1911, p. 687. "Daylight;" Nichols; Journal of the Franklin Institute, 1912, p. 315.

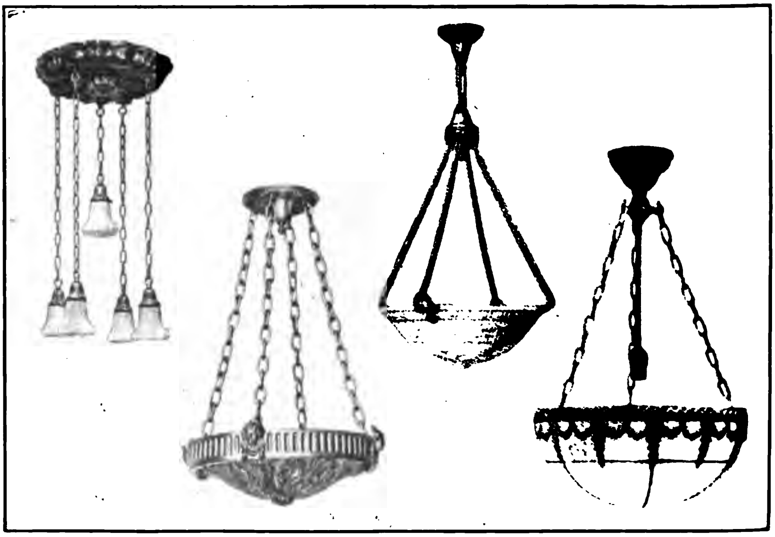


1.—REFLECTORS OF A DECADE AGO.



2.—VARIOUS FORMS OF MODERN REFLECTORS AND GLOBES.

1.—TYPICAL STOCK FIXTURES OF A DECADE AGO.



2.—MODERN FIXTURES.

The study of auxiliaries from the several viewpoints of light distribution, light absorption, color modification, dust depreciation, etc., has been an important part of recent developments in the field of illumination. The light distribution curve has become a familiar part of manufacturers' data and has been influential in emphasizing the importance of correct design and low light absorbing qualities for reflectors and globes. It has been shown that there have been marked improvements in the design of lighting auxiliaries. Likewise, there has been a notable growth in the knowledge of the use of such devices and in the discriminating selection of the best available for given purposes.

The literature of the art is rich in discussions of the physics[1] of light production, optical principles, color, etc. Knowledge of these subjects has been distributed rather rapidly through numerous presentations before organizations of men interested in lighting

In the measurement of light, notable progress has been made in recent years. The measurement of total flux and light distribution in the laboratory and the measurement of illumination intensity and brightness in lighting installations has been developed and now forms a standard part of illuminating engineering practice.

Beyond the introduction of certain refinements which have promoted accuracy of results, there have been no important developments in the practice of commercial photometry during recent years. Probably the most important development in this field has been the reduction in the size of photometers, which has resulted in making portable photometers available for the study of illumination. A recent broadening of the scope of such study has included the measurement of brightness as an important branch of photometry.[2]

A number of investigators are engaged in the study of the problem of photometry by nonocular means. The thermopile and the photoelectric cell, with possibly some alternatives, are looked to for assistance, in the future. While nothing of commercial practicability has yet demonstrated its value, progress is being made.

The variety of color values of the several important illuminants, and the other color values which for scientific purposes must be measured, create a requirement for standards of light of several widely different color values. There is a great need for a series of such standards which shall be authoritative by reason of the auspices under which they have been derived as well as by official designation. A number of laboratories are engaged in the study of this problem of heterochromatic photometry, and while concrete results in the establishment of such standards are not available yet, progress must be recorded in that the need for such standards is now definitely established and work is under way which should result ultimately in meeting this need. Present indications are that a range of calibrated color screens offers a most practical solution of this problem.[1]

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[1] Physics and chemistry: "Transformation of electric power into light;" Steinmetz; Trans. A. I. E. E., 1906, p. 789. "Color values of artificial lamps;" Stickney; Trans. Illg. Eng. Soc., 1907, p. 282. "The theory of flame and incandescent mantle luminosity;" Fulweiler; Trans. Illg. Eng. Soc., 1909, p. 635. "Luminous efficiency;" Trans. Illg. Eng. Soc., 1910, p. 113. "Some chemistry of light;" Whitney; General Elec. Review, 1910, p. 101.

[2] Photometry: "The integrating photometer;" Matthews; Trans. A. I. E. E., 1902, p. 39. "Illumination photometers and their use;" Millar; Trans. Illg. Eng. Soc., 1907, p. 548. "A new universal photometer;" Sharp and Millar; Elec. World, 1908, p. 181. "The integrating sphere in industrial photometry;" Sharp and Millar; Trans. Illg. Eng. Soc., 1908, p. 502. "Color measurements of illuminants;" Ives; Trans. Illg. Eng. Soc., 1910, p. 189. "Illumination tests;" Sharp and Millar; Trans. Illg. Eng. Soc., 1910, p. 391. "Photometry of large light sources;" Stickney and Rose; Trans. Illg. Eng. Soc., 1911, p. 641. "Photometry at very low intensities;" Bell; Trans. Illg. Eng. Soc., 1911, p. 671.

Standards of light [2] may be classified as primary, representative, and working standards. Primary standards, or those reproducible from specifications, are at present flame standards, respectively candles, the Hefner lamp, and the Pentane lamp. There have been no important developments in the way of primary standards of light in recent years, although certain means of arriving at a superior primary standard have been suggested and some research work has been done with that end in view. It is generally recognized that none of the existing primary standards of light is entirely satisfactory and that there is need for the development of a new and superior standard. Representative standards have been adopted and the so-called international candle is the official unit of light in England, France, and the United States. It is the result of standardization work of the past few years, and the unit is now represented by groups of seasoned, calibrated incandescent electric lamps held at the official laboratories of these three countries. These form a reasonably accurate and safe standard for light of one-color value. From them working standards are derived which accurately duplicate the value of the standard lamps and which are now available for general use of all who require them.

A start toward adopting a reasonable system of units and nomenclature [3] was made at the Geneva Electrical Congress in 1896. The committee on nomenclature and standards of the Illuminating Engineering Society has been actively engaged in the furthering of this work. That considerable progress has been made will be testified by the several annual reports of the committee to be found in the transactions of that society. The subject of nomenclature is especially vexing, and the art is fortunate in having the services of so distinguished a committee to assist in the adoption of sound definitions, symbols, and nomenclature. Pressure is being exerted with a view to the adoption of the metric system and some little progress appears to have been made toward this end.

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[1] Photometrical laboratories: "Photometrical laboratories of National Bureau of Standards;" Stratton and Rosa; Trans. A. I. E. E., 1905, p. 999. "A testing laboratory in practical operation;" Sharp; Trans. A. I. E. E., 1905, p. 1051. "Photometrical laboratory of the United Gas Improvement Co.;" Bond; Trans. Illg. Eng. Soc., 1909, p. 619. "Physical laboratory of the National Electric Lamp Association;" Hyde; Trans. Illg. Eng. Soc., 1909, p. 631.

[2] Standards of light: "Standards of light;" Nichols; International Electrical Congress, 1904; Steinmetz; Trans. A. I. E. E., 1908, p. 1319. "Report of the committee on nomenclature and standards;" Trans. Illg. Eng. Soc., 1909, p. 520. "Heterochromatic photometry and a primary standard of light;" Ives; Trans. Illg. Eng. Soc., 1912, p. 376.

[3] Units and nomenclature: "Reports of the committee on nomenclature and standards;" Trans. Illg. Eng. Soc., to date. "The concepts and terminology of illuminating engineering;" Sharp; Trans. Illg. Eng. Soc., 1907, p. 414.

The principles of physical optics and of magnetic flux underlie many calculations [1] made in illuminating practices. Marked impetus was given to calculations of illumination by the application of the idea of luminous flux in commercial illumination design. In recent years the mathematics of the subject has been set forth repeatedly, and it may be said that calculations involved in illuminating engineering work are perhaps further along toward complete development than is any other branch of the subject.

The subject of costs [2] is a fundamentally important feature of the science of illumination, and questions of first cost and operating cost, including maintenance and depreciation, must have the careful attention of the practitioner. The literature of this subject is rather meager, because of the difficulty of generalizing due to the marked influence which local conditions often exercise upon costs and due to the invidious form which cost discussions are likely to take.

So much for the purely engineering aspects of the illuminating art. The engineering features are important, indeed essential, but other aspects are equally so. The subject of vision in all its ramifications forms an integral part of the science of illumination, a fact which is being given due recognition. Light must be correct in respect to intensity, direction, diffusion, color, and steadiness; and to the study of these qualities a knowledge of visual processes and methods of perception is essential.[3] Shade perception and visual acuity together with color perception have been studied and discussed to an extent which begins to make known some of the more important facts pertaining to vision.

In this connection also the subject of contrast may be considered. A knowledge of the behavior of the human eye under various conditions of contrast is all essential to the science of illumination. Therefore the study of reflection and absorption of light and of brightness of surfaces is a prominent feature of the most recent advance in the science of illumination. Glare both from light source and from reflecting surfaces is largely a question of contrast, and its suppression in order to promote ocular welfare is one of the principal aims of the lighting practitioner to-day.[1] Excessive brightness means excessive contrast with surrounding objects.[2] Sometimes a light source, which is so bright as to occasion discomfort amid dark surroundings, becomes innocuous when amid bright surroundings. The general recognition of the need for contrast limitation has been effective in reducing contrast in the more recent installations.[3]

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[1] Calculations: "A rectilinear graphical construction of the spherical reduction factor of a lamp;" Kennelly; Trans. Illg. Eng. Soc., 1908, p. 243. "The calculation of illumination by the flux of light method;" Cravath and Lansingh; Trans. Illg. Eng. Soc., 1908, p. 518. "Calculating and comparing lights from various sources;" Hering; Trans. Illg. Eng. Soc., 1908, p. 645. "The law of conservation as applied to illumination calculations;" McAllister; Trans. Illg. Eng. Soc., 1911, p. 703.

[2] Costs: "The analysis of performance and cost data in illuminating engineering;" Harrison and Magdsich; Trans. Illg. Eng. Soc., 1911, p. 814.

[3] Visual processes: "Effects of light upon the eye;" Seabrook; Trans. Illg. Eng. Soc., 1908, p. 157. "Eyestrain and artificial illumination;" Krawell; Trans. Illg. Eng. Soc., 1908, p. 212. "Artificial illumination from a physiological point of view;" Standish; Trans. Illg. Eng. Soc., 1908, p. 254. "Eyestrain;" Pyle; Trans. Illg. Eng. Soc., 1909, p. 447. "Physiological effects of radiation;" Steinmetz; Trans. Illg. Eng. Soc., 1909, p. 683. "The psychology of light;" Woodworth; Trans. Illg. Eng. Soc., 1911, p. 437.

Glare is intimately connected with diffusion of light. It is a subject to which a great deal of study has been given within the last few years. In a paper before this institute Sweet presented the results of some laboratory experiments on the effect of glare due to the presence of a light source within the field of vision. While the conditions which he employed were extreme and the effect was exaggerated beyond that met in practice, yet the consequences experienced in ordinary installations differ from those found in his experiments only in degree. Glare due to exposed light sources means diminished seeing ability, discomfort, and possible injury to the eyes. Another effect also known as glare is that attending specular reflection from polished surfaces. This is a subject which has received especial attention during recent years. Glare of this kind is again a matter of excessive contrast. One views the imperfectly reflected image of a light source upon the page of a book, brightness of the image being far in excess of the immediate surroundings and the general surroundings. The same means which are effective in reducing contrasts between the light source and its surroundings are naturally effective in reducing the contrast between the reflected image of the light source and its surroundings. Thus in avoiding glare due to exposed light sources, glare due to specular reflection is likewise avoided.[4]

The engineering aspects, together with those aspects which pertain to vision, in large part constitute the science of illumination. Esthetics as comprehended in the principles of design, ornamentation, and decoration may, in a sense, be grouped under the science of illumination, and to the extent that it is so considered it is essentially important. Obviously, however, esthetics is so much a matter of artistic feeling that the entire subject can not be classed under this heading.[1]

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[1] Methods of perception: "Some physiological factors in illumination and photometry;" Bell; Trans. Illg. Eng. Soc., June, 1906, p. 3. "Allowable amplitudes and frequencies of voltage fluctuations in incandescent lamp work;" Ives; Trans. Illg. Eng. Soc., 1909, p. 709. "Physiological points bearing on glare;" Cobb; Trans. Illg. Eng. Soc., 1911, p. 153. "Notes on spectral character of light upon the effectiveness of vision;" Luckiesch; Trans. Illg. Eng. Soc., 1912, p. 135.

[2] Brightness: "Intrinsic brightness of lighting sources;" Woodwell; Trans. Illg. Eng. Soc., 1908, p. 573. "The measurement of brightness and its significance;" Ives; Trans. Illg. Eng. Soc., vol. 9, No. 3.

[3] Light absorption and reflection coefficients: "Coefficients of diffuse reflection;" Bell; Trans. Illg. Eng. Soc., 1907, p. 653. "Some experiments on reflection from ceilings, walls, and floor;" Lansingh and Rolph. Trans. Illg. Eng. Soc., 1908, p. 584. "Effect of the variation of the incident angle on the coefficient of diffuse reflection;" Gilpin; Trans. Illg. Eng. Soc., 1910, p. 854. "Reflection coefficients;" Bauder; Trans. Illg. Eng. Soc., 1911, p. 85. "Some reflecting properties of painted interior walls;" Jordan; Trans. Illg. Eng. Soc., 1912, p. 529.

[4] Contrast, glare, etc.: "Physiological points bearing on glare;" Cobb; Trans. Illg. Eng. Soc., 1911, p. 153. "Artificial illumination as a factor in the production of ocular discomfort;" Black; Trans. Illg. Eng. Soc., 1911, p. 166. "The effectiveness of light as influenced by systems and surroundings;" Cravath; Trans. Illg. Eng. Soc., 1911, p. 782.

A growing appreciation of the artistic possibilities of lighting and the growing demand for artistic execution in lighting design are gradually introducing more pleasing features, glassware, and lamps. It is one of the gratifying and encouraging features of the situation that there is nothing inconsistent in the requirements of good illumination whether they be requirements of efficiency, ocular hygiene, or esthetics. It appears that in promoting the one, natural impetus is given to one or both of the others. The more efficient light sources are likely to be more brilliant and to carry with them the need for concealment from view. In meeting this need, design along the lines of least resistance results in diffused light from larger areas, forming secondary sources which do not disturb ocular comfort. In the design of such systems of lighting, opportunities for the creation of pleasing and artistic effects thrust themselves upon the designer in a manner which was never encountered when less efficient illuminants of lower brilliancy were placed in rooms without adequate concealment.

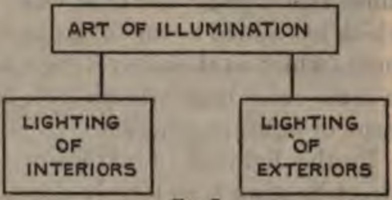

FIG. 7.

The art of illumination[2] is the lighting of interiors and of exteriors. The specialist applies daylight and artificial illuminants employing lighting auxiliaries and fixtures conforming to correct engineering, ocular, and esthetic principles in the lighting of interiors and exteriors. The art of illumination may be improved only as better materials of illumination are made available and as the science of illumination is advanced. In the lighting of interiors, more or less in accordance with established illuminating principles, much experience has been gained and recorded in recent years, and considerab advance in practice has resulted. In the transactions of the Illun nating Engineering Society alone there are more than 50 papers de ing with the illumination of interiors, many of them containi definite photometric data on the results obtained. This experien covers a wide variety of installations ranging from the illuminati of churches and theaters through illumination of stores and factori to the simpler problems of lighting garages and stables.

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[1] Esthetics, architectural principles, etc.: "Electric light as related to architecture;" Walker; Trans. Illg. Eng. Soc., 1907, p. 596. "The relation of architectural principles to illuminating engineering;" Jones; Trans. Illg. Eng. Soc., 1908, p. 9. "Modern methods of illumination from the architectural standpoint;" Castor; Trans. Illg. Eng. Soc., 1908, p. 271. "The relation of illuminating engineering to architecture from the illuminating engineering standpoint;" Elliot; Trans. Illg. Eng. Soc., 1908, p. 280. "Architecture and illumination;" Perrot; Trans. Illg. Eng. Soc., 1908, p. 619. "Illumination and architecture;" Furber; Trans. Illg. Eng. Soc., 1910, p. 822. "The architect and illuminating engineering;" Trimble; Trans. Illg. Eng. Soc., 1912, p. 51.

[2] Art of illumination.—Decorative aspects: "Light and color in decoration;" Hunter; Trans. Illg. Eng. Soc., 1908, p. 190. "The relationship of decoration to the illuminating engineering practice;" Clifford; Trans. Illg. Eng. Soc., 1910, p. 179. Church lighting: "Church lighting;" Perrot; Trans. Illg. Eng. Soc., 1908, p. 369. "Indirect lighting in auditoriums;" Wheeler; Trans. Illg. Eng. Soc., 1912, p. 163. "Church lighting;" Ely; Trans. Illg. Eng. Soc., 1912, p. 613. Lighting of auditoriums and theaters: "The illumina-

That remarkable advances have been made in the lighting interiors during the last five years will probably not be deni Better materials of illumination are available and knowledge of co rect principles of illumination has increased rapidly. Experimen in the design of lighting equipment and its installation have som times failed to give satisfaction, but usually have given some less which has added to the total experience in lighting practice. Develo ments which in themselves have not achieved permanent success ha in some cases been stimulative, and have promoted the best develo ment of lighting practice.

In the lighting of exteriors there has been some advance als Street lighting is so largely dependent upon municipal appropriatio that its development is sometimes hampered unduly by lack of func Merchants' associations have found in street lighting a means of pr

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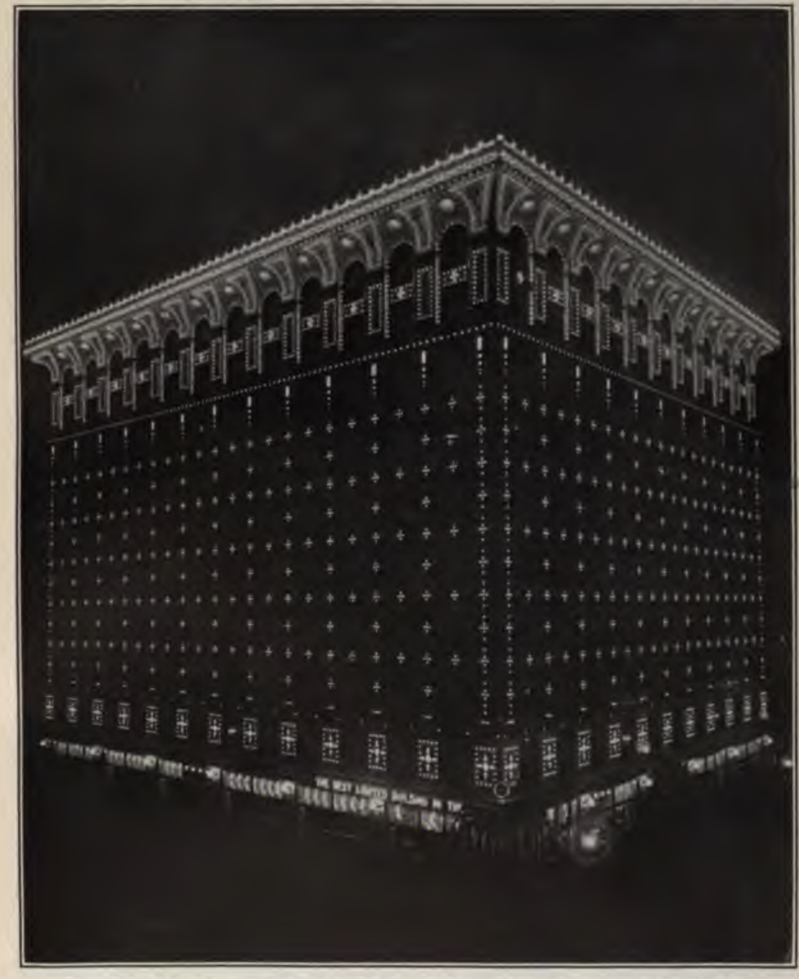
tion of Hammerstein's Philadelphia Opera House;" Spillman; Trans. Illg. Eng. Soc., 1909, p. 385. "Th ter illumination;" Vaughn and Cook; Trans. Illg. Eng. Soc., 1911, p. 961. Office lighting: "The illumi tion of the building of the Edison Electric Illuminating Co. of Boston;" Bell, Marks, and Ryan; Tr Illg. Eng. Soc., 1907, p. 603. "Illumination of the Engineering Societies' Building, New York;" Kn Trans. Illg. Eng. Soc., 1907, p. 445. "Illumination of the office building of the Philadelphia Electric Co Bartlett; Trans. Illg. Eng. Soc., 1908, p. 555. "Indirect illumination of the general offices of a large co pany;" Aldrich and Mailia; Trans. Illg. Eng. Soc., 1914, p. 103. "Some engineering features of of building lighting;" Edwards and Harris; Trans. Illg. Eng. Soc., 1914, p. 164. School lighting: "Sch house illumination;" Hatch; Trans. Illg. Eng. Soc., 1907, p. 359. "Public-school room lighting;" Kni and Marshall; Trans. Illg. Eng. Soc., 1910, p. 553. Library lighting: "Design of the illumination of New York City Carnegie libraries;" Marks; Trans. Illg. Eng. Soc., 1908, p. 538. Store lighting: " lighting of a large store;" Law and Marshall; Trans. Illg. Eng. Soc., 1911, p. 186. "Department-st lighting;" Shalling; Trans. Illg. Eng. Soc., 1913, p. 17. "Distinctive store lighting;" Law and Pow Trans. Illg. Eng. Soc., 1913, p. 515. "Present practice in small-store lighting;" Law and Powell; Tra Illg. Eng. Soc., 1912, p. 435. Factory lighting: "Factory lighting;" Marks; Trans. Illg. Eng. Soc., 1 p. 805. "Mill lighting;" Stickney; Trans. Illg. Eng. Soc., 1911, p. 478. "Factory lighting;" Flex and Dicker; Trans. Illg. Eng. Soc., 1913, p. 470. Show-window lighting: "Show-window lighting;" H ninger; Trans. Illg. Eng. Soc., 1912, p. 178. "Show-window lighting;" Wheeler; Trans. Illg. Eng. So 1913, p. 555. Residence lighting: "Residence lighting;" Cravath; Trans. Illg. Eng. Soc., 1906, p. 1 "Some home experiments in illumination from large area light sources;" Ives; Trans. Illg. Eng. S 1913, p. 229. "The lighting of a simple home;" Powell; Trans. Illg. Eng. Soc., 1914, p. 45. Passenger- lighting: "The lighting of railway cars;" Hulse; Trans. Illg. Eng. Soc., 1910, p. 75. "Illuminatior passenger cars;" Minick; Trans. Illg. Eng. Soc., 1913, p. 214. "Modern practice in street railway illumi tion;" Hibben; Trans. Illg. Eng. Soc., 1913, p. 589. "The illumination of street railway cars;" Por and Staley; Trans. Illg. Eng. Soc., 1914, p. 25. General: "Indirect illumination;" Curtis and Morg Trans. Illg. Eng. Soc., 1908, p. 740. "Daylight illumination;" Marsh; Trans. Illg. Eng. Soc., 1908, p. 2 "Symposium on indirect, semi-indirect, and direct lighting;" Rolph, Henninger, and Hibben; Tra Illg. Eng. Soc., 1912, p. 234. Street lighting: "A method of street lighting by incandescent lamp Underwood and Lansingh; Trans. Illg. Eng. Soc., 1906, p. 115. "Lighting of streets by the incandesc mantle burner system;" Westermaier; Trans. Illg. Eng. Soc., 1906, p. 122. "Street lighting;" B Trans. Illg. Eng. Soc., 1908, p. 400. "Street lighting by tungsten lamps;" Rhodes; Trans. Illg. E Soc., 1909, p. 54. "Some neglected considerations pertaining to street illumination;" Millar; Trans. I Eng. Soc., 1910, p. 653. "Street lighting with ornamental luminous arc lamps;" Halvorson; Trans. I *Eng. Soc.*, 1913, p. 88. Lighting of building exteriors: "The lighting of the Buffalo General Elect *Co.'s buil* [illegible] an; Trans. Illg. Eng. Soc., 1912, p. 597.



BUILDING OF THE DENVER GAS AND ELECTRIC CO. AS LIGHTED AT NIGHT.

moting trade, and have had recourse to display street lighting to supplement the lighting provided by the city. Thus, tungsten cluster lighting has been installed in many cities, particularly the smaller cities of the country, with a very beneficial effect upon street lighting as a whole. More recently a competitive form of illumination, known as the ornamental arc lamp system, in which an inverted arc lamp is employed, has commanded much attention and is experiencing notable growth. General civic street lighting is improving slowly, the average standard of intensities being increased, and somewhat better design of the illuminants and systems being noted in the more recent installations.

There is some little development in the way of lighting exteriors of buildings. Outline lighting of expositions was first carried out in a notable manner at the Columbian Exposition in 1893, attaining perhaps its highest development at the Pan-American Exposition in Buffalo in 1901. The Jamestown Exposition struck a new note in lighting building exteriors, and in the Panama-Pacific International Exposition in San Francisco, 1915, we are promised a fuller development of the lighting of buildings by concealed sources.

These occasional remarkable installations are, of course, few in number. There is no general tendency to light the exteriors of buildings, though a few creditable attempts have been made in this direction.

PROGRESS IN ILLUMINATION.

Having reviewed briefly the recent developments in the field of illumination, allow me to direct your attention briefly to the subject of progress and to the forces which have been responsible for improvements in the past and to which we must look for further development.

The illumination which is provided depends not only upon the status of the art but also upon the degree to which practice conforms with the art.

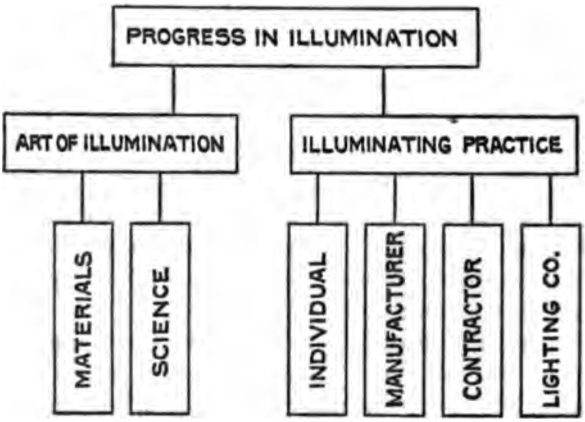


FIG. 8.

It has been stated that the art of illumination is improved as the materials of illumination are bettered and as the science of illumination is advanced. It may now be added that illuminating practice is improved as individuals, manufacturers in the lighting field, contractors in the lighting field, and lighting companies better their practice. It is to be regretted that in a review of recent progress in the field of illumination, note must be taken of the fact that illuminating practice has not advanced as rapidly as the development of the materials of illumination and the advance of the science of illumination would appear to make possible. The art of illumination has made rapid strides. Manufacturers, contractors, and lighting companies have improved their practice in many instances. Unfortunately, however, their influence is largely confined to new installations in stores and to some large manufacturing establishments. Where the commercial incentive is clearly discernible, old installations have been brought up to date very generally. With these exceptions the older installations, dating back 10 years or more, compare unfavorably with the best that the art affords.

Broadly speaking, a review of recent developments throughout the entire field must prove encouraging to all who are interested in the subject of illumination, with the single exception that means have not yet been devised for bringing old installations up to date and into conformity with present day knowledge of lighting principles.

FORCES TENDING FOR BETTERMENT IN THE ILLUMINATION FIELD.

The progress of the past few years in the field of illumination is largely traceable to definite sources, and consideration of these sources warrants the belief that recent progress may be taken as an earnest of further progress to be anticipated for the near future. The Illuminating Engineering Society is a forum for the discussion of lighting questions. It fosters study in the field, collects in its transactions most of the important literature of the art, and seeks to disseminate information regarding illumination. The Johns Hopkins University Illuminating Engineering Society lecture course on illuminating engineering laid the groundwork for educational courses devoted to the subject, and a committee on education of the Illuminating Engineering Society is now seeking to further pedagogic interest and activity along this line. The national associations of electric companies and of gas companies are doing educational work in this field. The Illuminating Engineering Society is conducting a campaign of popular education. All of these efforts have made for progress, and may be looked to for future progress. The manufacturers of illuminants and accessories in this country are remarkably progressive. Their researches and investigations and educational work are bringing large results throughout the entire field. Lighting companies are awakening to the importance of illumination. While perhaps the power business in both the electric and gas industries is assuming greater importance than the lighting business, yet it is the lighting business upon which the reputation of the company for furnishing good service or poor service is most likely to depend, and which offers far more opportunity for cultivating public good will through acceptable service than does the power business. Most large electric and gas companies now have on their staff one or more illuminating engineers, and are devoting more attention than formerly to the subject of good illumination.

IMPORTANCE OF THE SUBJECT.

In conclusion, allow me to enter a plea for more general attention to the subject of illumination. It is one of transcending importance whether viewed from a humanitarian or a commercial standpoint. Some estimates for the year 1913 of its commercial importance in this country have recently been published.[1] According to these the manufacturer's sales of materials employed directly for illumination in the electric-lighting industry alone aggregated $65,000,000, while the sales of machinery involved in the generation of electricity for lighting purposes aggregated perhaps half of this amount. The revenue of central stations derived from the electric-lighting business is estimated as exceeding $300,000,000. These figures suggest in some measure the importance of the electric-lighting industry and, of course, are in need of supplement by corresponding figures representative of the gas-lighting industry and of the miscellaneous lighting business of the country. But if all such figures were available, they would only begin to suggest the commercial importance of artificial illumination to the country. Who shall attempt to estimate the colossal additions to the wealth of the Nation which it makes possible through extending the hours of industry?

The importance of artificial illumination in another sense is difficult to overestimate.

"Health in the home is dependent upon proper sanitation. 'Cleanliness is next to Godliness'; without proper light, cleanliness is next to impossible. Adequate illumination promotes cleanliness.

"Ophthalmologists tell us that inadequate or otherwise improper illumination occasions eyestrain which often results in headache and other nervous disorders. These, if prolonged, sooner or later undermine general health. So, good illumination affects general health by promoting sanitation and avoiding nervous strain.

"Good illumination has a more direct bearing upon the health of the eyes. If the eyes are closely employed upon detailed work, as in sewing or reading, under conditions of illumination which are improper, the eyes are fatigued, and if the occupation is continued, in spite of the fatigue, vision is impaired at least temporarily, and possibly is injured permanently. As compared with our forefathers we are distinctly a nocturnal people. We use our eyes a greater number of hours per day. Oculists' records testify, and the prevalence of eyeglasses evidences, the deleterious effects upon the vision of the people as a whole. Who shall say what part of the prevalence of impaired vision is attributable to improper illumination, that is to say, to the misuse of light?

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[1] Editorial, Lighting Journal, January, 1914.

"Physiologists tell us that the human eye is naturally adapted for distant vision; that when focused upon nearby objects, as in most of the work in which it is applied in our modern life, the muscles are contracted and the focal mechanism of the eye is subjected to strain. They tell us also that, just as children are physically, intellectually, and morally more susceptible and pliant than adults, so the visual organs of children are delicate and especially liable to injury if used under adverse conditions. In modern life children are called upon for a large amount of home work in connection with the school systems. This involves application of the eyes in exacting near vision to which they are not naturally adapted, and at a time of life in which they are peculiarly liable to injury. When to these untoward conditions there is added that of poor illumination, is it any wonder that we are becoming a bespectacled race? Of these conditions which operate against ocular welfare some may be beyond our control, but that of poor illumination is a menace for the existence of which there is no excuse, since the remedy is understood and is available to all.

"Light has a marked bearing upon the usefulness of our lives. Artificial light extends the hours in which we may labor. It makes possible intellectual improvement; it permits added achievement; it makes actual life of 50 years equivalent to a much longer life in the period antedating the perfection of our modern light sources. Yet, though these statements are in general correct, it remains true that the precise measure of added usefulness which artificial light makes possible depends upon the merits of the illumination. With good illumination one may labor to better effect, may produce more largely, and the product will be more nearly perfect than with poor illumination. These facts may be applied to the industries and to the arts, to manufacture, to the pursuit of knowledge, or to the development of artistic talent.

"Artificial light is an important factor in promoting happiness. In extending the hours of activity beyond those which are ordinarily devoted to the duties of life, it affords opportunity for the pursuit of pleasure. Light reveals the beauties of nature and of art, whether it be sculpture, painting, or architecture. It is particularly important in the home where so much effort is expended for the comfort and pleasure of the family. Few homes are so humble but that some effort is made to render them attractive. The home usually reflects in its decorations the personality of the home maker, and, within the limits of the tastes and means of the family, attempt is generally made to render it homelike and charming. Much of the beauty and charm are lost in the evening if the rooms are not properly illuminated."[1]

Considering the immense importance of artificial illumination as a factor in the progress of the country, every advance in the science of illumination, every improvement in the materials of illumination, and all progress in the art has a special significance—even a minor improvement in materials or in the science may have a large general influence if embodied in standard practice. It is therefore of interest to consider the improvements which have been brought about in the recent past, the discrepancy between some of the present practice and the best that the art affords, and the opportunity which each one of us has to influence one or more lighting installations for good. Considering the importance of the subject and the progress being made, it is a gratifying task to undertake to report upon recent developments, even though such report is recognized as being but little more than suggestive as to the facts.

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[1] P. S. Millar, Froebel Society, Brooklyn, November, 1913.

THE LOOM AND SPINDLE: PAST, PRESENT, AND FUTURE.[1]

By Luther Hooper.

[With 11 plates.]

I. PRIMITIVE LOOMS: PREHISTORIC, ANCIENT, AND MODERN.

The spindle and the loom, the one for twisting fiber into thread and the other for weaving the thread itself into cloth, are prehistoric and almost universal tools.

These tools, and the methods of using them, have never been subject to much variation, whether invented by prehistoric man, the skillful weavers of the ancient world, or the ingenious craftsmen of the primitive tribes of to-day.

Moreover, it is not only in elementary forms of weaving that this similarity is found, for if the essential principles of the most modern spinning and weaving machinery be investigated, it will be seen that they are identical with those used in the most ancient times. The complicated textile machinery of to-day is, therefore, simply a natural development from that used by primitive weavers of all time.

In the present course of lectures my intention is to demonstrate the principles of the primitive loom and spindle, and trace their gradual development into the wonderful, but still far from perfect, mechanism of the modern machines actuated by steam power; also to indicate the lines along which textile machinery, in the future, is likely to be improved.

In this first lecture I shall occupy the time at my disposal by a description of primitive spinning and weaving appliances, prehistoric, ancient, and modern.

Prehistoric examples of the weaver's art are extremely rare. This is owing, of course, to the perishable nature of the materials of which they are composed. Few as they are, however, and consisting, as they do, of the merest shreds of textile fabrics, they show unmistakably that the art of the loom, as well as that of the spindle and needle, was understood and successfully practiced in what has been poetically called by an eloquent French writer "The night of time."

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[1] Canton Lectures delivered before the Royal Society of Arts, London, February 26, March 4 and 11, 1912. Reprinted by permission from Journal of the Royal Society of Arts, September 6, 13, 20, 1912.

A large number of the illustrations are taken from Mr. Hooper's "Hand-Loom weaving" and are reproduced by the courtesy of the publisher, Mr. John Hogg.

The term "prehistoric" has, of course, only a relative meaning. Roughly speaking, history begins at the period in human development when the use of metal for tools and ornaments supersedes that of stone. I believe I am right in stating that antiquities of the Age of Stone are classed as belonging to prehistoric time.

It is generally agreed that most of the lake dwellings of Switzerland, which were discovered and eagerly investigated during the last century, belong to the neolithic, or later stone period. It was amongst the remains of one of the earliest of these villages, discovered in the bed of the lake at Robenhausen, that bundles of raw flax fiber, fine and coarse linen threads, twisted string of various sizes, and thick ropes, as well as netted and knitted fabrics and fragments of loom-woven linen cloth, sometimes rudely embellished with needlework, were found. There were also spindle whorls and loom weights of stone and earthenware, one or two fragments of wooden wheels, which might have formed parts of thread-twisting machines, as well as rude frames which were possibly the remains of simple looms.

It is remarkable that these relics of primitive weaving were found in the lowest of three villages, which, during successive ages, had been built on piles on a common site near the margin of the lake. The linen shreds bear evidence of having been partially burned, and they were found very deeply buried in the clay which forms the bed of the lake. It has been supposed that this early village was destroyed by fire, and that to this accident we owe the preservation of the precious relics. All traces of actual textile fabrics are absent from the later villages, although loom weights and spindle whorls are found in them all.

This theory of accident may be true or not, but however the partially burned specimens of flaxen materials became embedded and preserved, they demonstrate that the people of the stone age in Europe cultivated flax and hemp, prepared and spun the fibers into continuous thread, doubled and twisted it into various thicknesses for different uses, and netted, knitted, or wove it into fabrics of a sort which required a good deal of ingenious contrivance for their production.

Keller's work on the lake dwellers of Switzerland is illustrated with a large number of lithographic drawings. I have had a few of these photographed, as they show the construction of the textiles more clearly than photographs of the actual discolored fragments of cloth and thread would do.

[Photographs of illustrations from Keller's "Lake Dwellings of Switzerland," Longman, 1892, were here thrown on the screen.]

Discoverers of such relics as these are often apt to exaggerate in their imagination the attainments of the people who produced them. Thus, Prof. Messekommer, who in 1882 was fortunate enough to find the most important and probably earliest of the lake dwellers' villages at Robenhausen, as already described, says that "he is convinced, from the specimens of textiles there found, that all manner of weaving was thoroughly known at the very beginning of the lake-building period." An expert examination of these fragments, however, does not bear out his assumption. They are, as we have seen, all webs of the very simplest kind, and are just such as are woven by savage people of to-day, by means of the most elementary weaving appliances. No traces of tools for textile work were found beyond whorls for spindles, one or two charred spindles with thread wound on them, sharp-toothed combs, which were probably used for preparing the raw fiber, and a few weights of earthenware, similar to those which were used by the Greeks and Romans for weighting the warp threads of their upright looms.

In reconstructing the life and operations of ancient and prehistoric man from the scanty relics which are available, it is most reasonable to imagine that weaving, and in fact work of all kinds, was carried on with the maximum of human craft and patience and the minimum of mechanical contrivances. We should not imagine how quickly and easily things might have been made, but how simply, even though with infinite pains, the work could have been done.

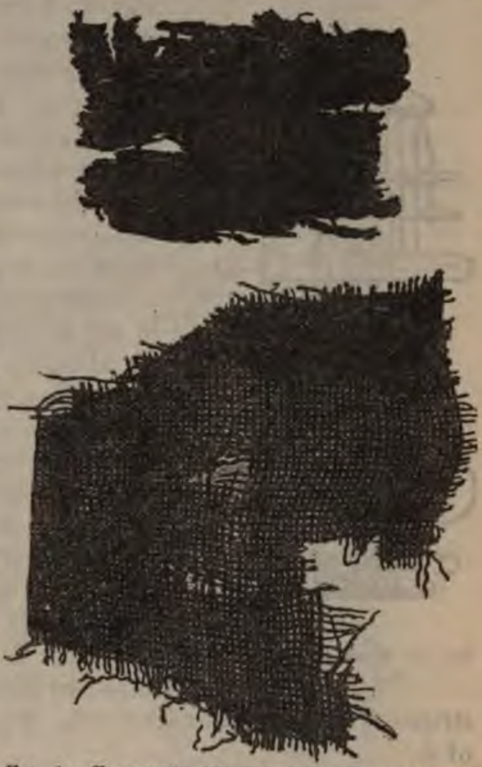

FIG. 1.—Fragments of linen cloth, woven by the prehistoric lake dwellers of Switzerland.

Bearing this in mind let us examine two interesting relics of the handiwork of a prehistoric weaver shown in figure 1.

These are not, like so many of the fragments, netted or knitted from a single thread. This is proved by the regular and flat interlacement of its strands, which cross each other at right angles. However small the original webs may have been, a set of threads—the warp—must in each case have been stretched on some kind of frame. The intersecting threads—the weft—must also have been passed before and behind alternate warp threads in regular sequence. This could only have been done on a loom, however simple, and how simply a loom may be constructed let me exemplify.

Here is an oblong board, two sticks, and a piece of string.

If I wind the string onto the board (fig. 2) and insert the two sticks between alternate cords at one end, I have made the board and sticks into a simple loom, which is typical of the loom of every country and of all time. It is typical because it has the essential characteristic of all looms, which is the crossing of the threads between the sticks. This cross transforms a collection of any number of separate strings into a well-ordered weavable warp, which can easily be kept free from entanglement. In fact, without it no weaving could begin, much less be carried on to any length.

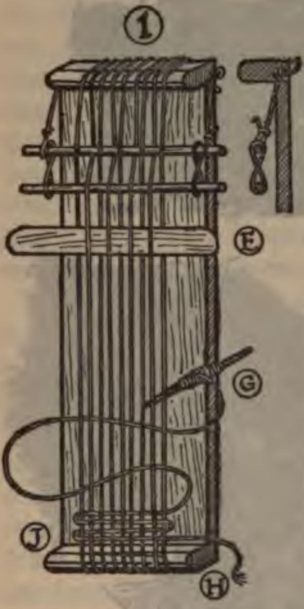

FIG. 2.—Primitive board loom and shed sticks.

There is a roll of East African weaving in the ethnographical gallery of the British Museum. This beautiful strip of cloth is 4 inches wide and is a fine specimen of modern primitive weaving. The pretty web, with its delicate pattern of checkers, could quite easily be woven on such a board as this, no other appliances being necessary than the two or three sticks and a long thin spindle or needle for inserting the weft thread.

Here is a tiny board loom, on which I have had woven a copy of one of the border stripes of the African native web. Figure 3 (pl. 1) is a photograph of it.

You will notice a number of loops hanging loosely to the unwoven threads. I need not refer to them just now, except to say that they are for the purpose of economizing time and facilitating the work. Without them the weaving would take longer and require a little more attention, but otherwise could be as well done.

If we take a piece of loom-woven coarse canvas and examine it, we shall see clearly the stretched threads of warp and the continuous intersecting thread of weft. If a small fragment of such a piece of textile had been partially burnt and buried in clay at the bottom of a lake for 3,000 years or more, then, discovered by a fortunate arche-

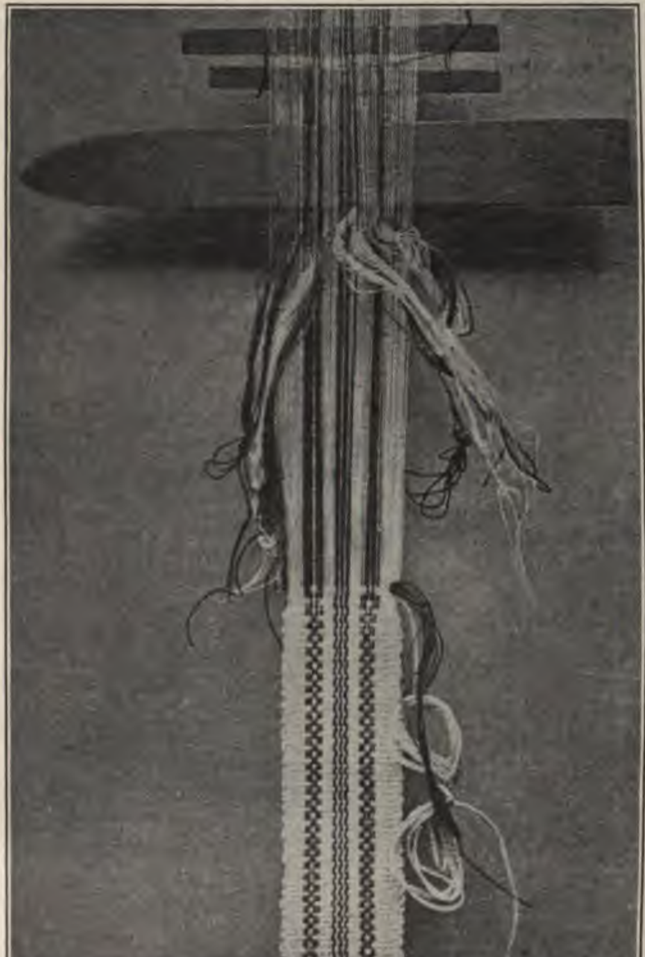

FIG. 3.—COPY (IN PROGRESS) OF A PORTION OF AN EAST AFRICAN WEB.

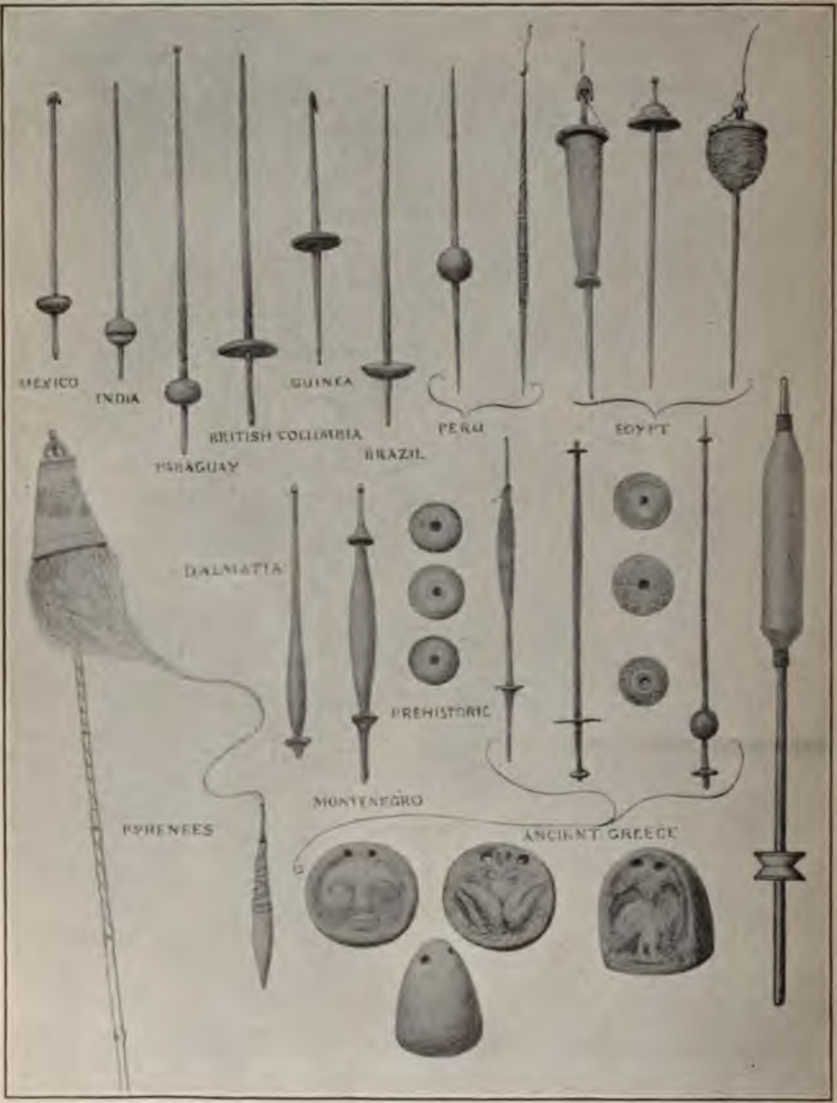

FIG. 4.—A COLLECTION OF PRIMITIVE SPINDLES, A DISTAFF, AND SOME LOOM WEIGHTS FROM VARIOUS COUNTRIES.

(Drawn by the author.)

ologist, had been pressed between two glasses for preservation in a museum, it would, I think, when photographed present very much the appearance of the shred of lake dwellers' linen cloth (fig 1).

I can best illustrate the method of intersecting warp and weft on my extemporized primitive loom.

[Here the lecturer gave a demonstration of the simplest kind of weaving.]

Before proceeding to inquire into particulars regarding the form of loom used by the lake dwellers, it will be advisable to make a digression in order to describe the art of making thread, which naturally precedes the art of weaving.

There is no natural continuous thread except silk, all others being artificial. Silk is unwound from the cocoon of the silkworm in lengths of from 500 to 1,000 yards.

Of this thread primitive man is unaware. But he seems to have an instinct which teaches him that various vegetable and animal fibers, however short they may be, can be twisted together and joined up into threads of any required length and thickness, as well as of great strength. Weaving is well nigh universal, but even in the few places where it is unknown the art of making very perfect thread and netting it into useful fabrics is commonly practiced.

The process of making thread may be stated very briefly. It consists of (1) stripping and cleaning the fibers; this is called skutching or ginning. (2) Of loosening and straightening out the cleansed fibers; this is termed carding. (3) Of drawing the carded filaments out in an even rove and twisting them together into fine or coarse continuous thread. This final process is called spinning.

The arts of spinning and weaving have acted and reacted continually on one another. This was notably exemplified during the eighteenth century in this country. At the beginning of the century weavers were often hindered by having to wait for yarn to weave, the domestic system of spinning by hand not being sufficient to keep pace with the production of cloth. This led to the invention of spinning machinery. By means of this machinery the output of yarn soon became greater than the hand-loom weavers could cope with, although there was still a growing demand for textile fabrics. The application of steam power to the loom and many improvements added to the loom itself increased the speed of weaving and again equalized the output of the two industries.

There can be no good weaving without good spinning, for good cloth can not be made of bad thread. Spinning can be done slowly, of course, without any mechanical aid whatever.

Here is a bundle of fiber ready for spinning. It has been simply cleaned and carded. If I draw out a few fibers and, after slightly damping them with clear water, twist them together with my fingers, you will see that they have been converted, simply by the twisting, into a strong thread. Thread thus casually made is naturally coarse and rough, but an expert spinner would make in the same way a fine, strong, even thread with very few fibers.

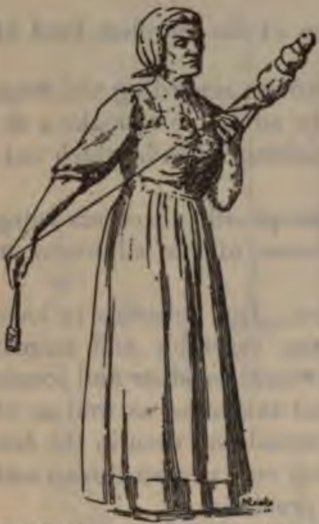

Fig. 5.—Peasant spinning. (Present time.)

If a small stick, having a hook at one end and a weight at the other, be suspended to the spinning thread, the further even twisting of the yarn will become much easier, because regulated by the continuous revolution of the weighted stick or spindle, as such an appliance is called. The spindle is also useful for winding the twisted or spun thread upon.

Figure 4 (pl. 2) shows a collection of primitive spindles, both ancient and modern. A moment's consideration of it will show how widely distributed and well-nigh universal this simple industrial implement has been. One great advantage the spindle has over all other spinning appliances is that it can be carried about by the spinner without her having to discontinue her work. An ancient story by Herodotus illustrates this point.

King Darius chanced to see a Pæonian woman who was carrying a pitcher on her head leading a horse and spinning flax. He sent spies after her, and they reported that she filled the pitcher with water, watered the horse, and returned, continuing all the while to spin with her spindle. Darius asked if all the women of Pæonia were so industrious; and being told they were, ordered that all the Pæonians, men, women, and children, should be removed from their own country into Persia.

Whether this reward of merit was appreciated by the Pæonians Herodotus does not say.

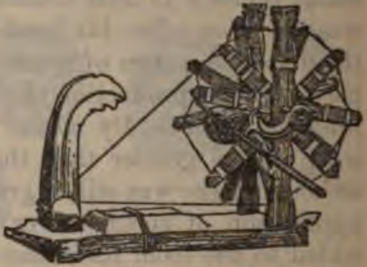

Fig. 6.—Native spinning wheel. (From Sarawak.)

There is a painting on a Greek vase of about 500 B. C. which depicts a spinner holding the distaff in a picturesque and graceful but unusual and, one would think, ineffective way.

Figure 5 shows the usual method of carrying the distaff, which, it will be seen, leaves both hands of the spinner free for drawing out the fiber and twisting the spindle.

Figure 6 is from Roth's "Natives of Sarawak" and shows the spindle attached to a small wheel, actuated by a large one, which keeps it regularly rotating.

With this wheel, as with the weighted spindle, twisting and winding on are alternate operations. The manner of using the wheel is as follows: The thread is first tied to the spindle, a convenient length of fiber being drawn out. The spinner turns the large wheel, which causes the spindle to revolve and twist the length of fiber, the latter being held in a line with the spindle. When sufficient twist has been given to the thread, the spinner adroitly moves the hand holding it so that the thread is brought at right angles with the spindle. The rotation of the wheel being continued in the same direction, the length of spun thread will be quickly wound upon the spindle. These alternate movements are repeated until the spindle is conveniently filled up with spun thread.

Spinning wheels working on this principle are widely distributed. They are still used in China and Japan and various countries of the East; also in Central America, as well as in many remote islands where native textile arts still survive. The large spinning wheel, still used in parts of Ireland, Wales, and Scotland for spinning wool, works in this manner. In Scotland it is called the muckle wheel.

Spinning with a wheel may have been practiced in Europe in ancient times, but there is no evidence to prove it. The thread is the same whether spun with or without the help of a wheel. The best and finest workable thread ever produced has been spun in India by means of the spindle, at Dacca, where the famous Dacca muslins are still woven by hand from hand-spun thread.

The well-known ordinary spinning wheel, sometimes called the Saxony or German wheel, has been in use since the sixteenth century. It has an ingenious arrangement by means of which the two operations of twisting the thread and winding it are done simultaneously. As, however, it carries the art of spinning beyond the primitive stage, I must leave its description to my next lecture.

After this rather lengthy but necessary digression we may resume the inquiry as to the loom in its ancient and primitive form.

The presence amongst the textile relics of the lake dwellers of a few circular and conical-shaped objects of stone and earthen ware, gives a clue to the form of loom on which the prehistoric webs were woven. Such objects, pierced with holes and sometimes elaborately ornamented, are found in excavations all over Europe. These objects are precisely like the weights which the Greeks and Romans and other ancient European peoples used for the purpose of stretching the threads of warp in their peculiarly constructed upright looms. (See fig. 4, pl. 1.)

Seeing, then, that similar objects to these are found amongst the lake dwellers' relics, it is reasonable to conclude that they were used for the same purpose, and that the form of the prehistoric loom was the same as that of the looms of a later period of which we have representations.

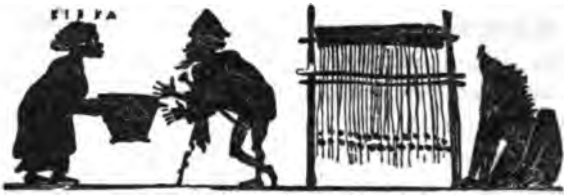
FIG. 7.—Greek loom. (From Bœotian vase painting. 500 B. C.)

Amongst the vase paintings of ancient Greece only four representations of the loom are found. Two of these are rough though expressive caricatures painted on Bœotian pottery. The loom in each of these sketches is very definite and, as far as it goes, evidently correct in detail. One of these painted pots is in the Bodleian Museum at Oxford, and the other, of which I have a photograph, is in the British Museum.

The subject of the painting is Kirke presenting the noxious potion to Odysseus (fig. 7). The loom is simply a pair of upright posts with a crosspiece joining them together at the top. Beneath the crosspiece is a roller or beam on which the cloth is wound as it is woven. The unwoven warp is seen hanging nearly to the ground, where it appears to terminate in two rows of circular weights. These weights keep the warp threads taut, and two sticks intersect the threads in order to retain the cross between them alternately, so keeping the warp from entanglement and preserving an opening for the passing and interlacing of the weft. In the Oxford vase the weft is shown wound on a kind of mesh such as is used in the making of nets.

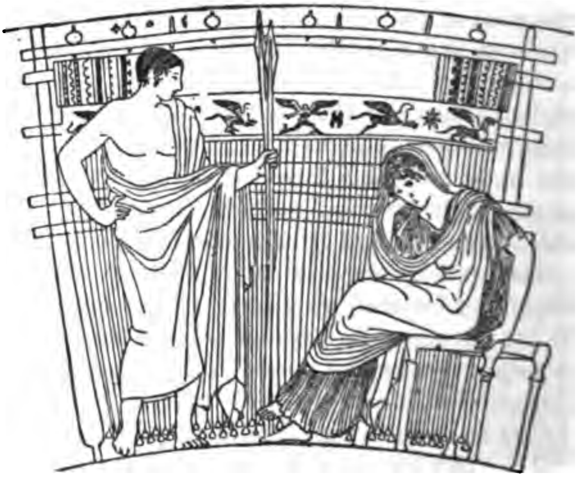
FIG. 8.—Penelope's loom. (From Greek vase painting. 500 B. C.)

Figure 8 is copied from a beautiful Greek vase painting. Its date is about 500 B. C. This is a much more careful and elaborate painting, but it tells little more about the loom and its arrangement. The loom is of the same simple construction, but all the parts are more carefully drawn and the pattern of the web—a highly ornamental one—is distinctly shown. There are also pegs on the top crosspiece of the loom on which spare balls of different-colored weft are kept handy for use. Spare warp was also probably hung from them at the back of the loom.

The weights at the bottom of the loom in this case are of a conical shape, very much like those found in Switzerland. There is also at the back of the loom another stick or beam, which is, I believe, for the purpose of holding the length of unwoven warp before it passes through the holes in the weights at the bottom of the loom. The loose back threads are not shown in the painting, but the roll of cloth upon the beam indicates that more than a loom's length of warp is being manipulated. Probably the artist shirked the difficulty of representing these back threads, and so made the front ones appear to terminate at the weights.

This painting is particularly interesting, because it shows unmistakably that the elaborate pattern webs, which the classic poets so often referred to, were woven on the simplest of looms by skillful handicraft, not by means of complicated machinery, as some have supposed. In proof of this, if you will notice the border of grotesque creatures which Penelope has just woven, you will recognize its likeness to the pattern on the robe of a processional figure, copied from another vase painting of the same period, which is the subject of figure 9.

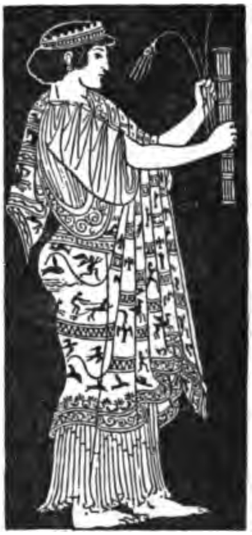

FIG. 9.—Processional figure. (From a Greek vase painting. 500 B. C.)

On a tiny vase in the British Museum there is a slight sketch of a lady weaving on a small frame, which she holds on her lap.[1] In this case the strings of warp are merely stretched on the frame, and there are no loom weights. There is, however, a peculiarity in the method of working depicted which unmistakably links this diminutive loom with those of Kirke and Penelope, as we shall presently see.

Olaf Olafsen, in a work on Iceland, published in Amsterdam in 1780, gives an illustration and account of a traditional loom still used at his time in that country. There are two or three more or less imperfect copies of Olafsen's drawing in English books which show the striking points of resemblance this loom bears to the looms of ancient Greece.[2]

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[1] Gallery of Greek and Roman life, B. M.

[2] One of these is an illustration to the article "Tela," in Smith's "Dictionary of Greek and Roman Antiquities."

Looms constructed in the manner which required the kind of weights found in the lake dwellings, those depicted in use on the classic vases, and the traditional looms of the north of Europe, all agree in requiring a method of weaving which differs from that of all other looms the world over. This peculiarity was noticed by Herodotus, who visited Egypt about 400 B. C., and recorded his impressions. Speaking of the Egyptians, who appeared to him to do everything in a contrary manner, he says: "Other nations"—meaning, of course, Europeans—"throw the wool upward in weaving, the Egyptians downward."

Now, if you will glance again at figures 7 and 8, after you have noted the point on the Icelandic one, you will see that the webs on these looms are all being woven from the top. This necessitates beating the weft upward as the Greek historian says, and also winding the cloth upon the top roller. In fact the method of stretching the warp by the hanging weights and the necessary relative position of the cross sticks make it impossible to weave in any other way.

The Greek lady weaving on a small frame I referred to is also shown commencing at the top, although in her case the warp being stretched upon a frame, it is not necessary to weave in what we should consider an awkward way; her doing so, however, shows that it was the custom to which she was used.

The people of ancient Egypt did a large export trade with Europe and distant parts of Africa and Arabia in manufactured linen, the fine linen of Egypt being unrivaled in the ancient world for evenness and fineness of texture.

Owing, no doubt, to the dryness of the climate of Egypt, and the peculiar funeral customs of the Egyptians, many specimens of ancient Egyptian textiles have been preserved. Linen cloth, which was woven four or five thousand years ago or even more, may still be seen and handled, being as perfect as when it was newly cut out of the loom by the industrious Egyptian weaver.

In the British and other museums many examples of such Egyptian linen textiles may be seen. These linen cloths were unwrapped from the mummies whose funerals took place under the various dynasties. As to the looms on which these textiles were woven, the few representations of them which exist show that they were constructed on a different plan from those of Europe, and bear out the statement of Herodotus that the Egyptians beat the weft downward instead of upward when weaving.

Only three pictures of ancient Egyptian looms are known to exist, and there seem to be no traces or fragments whatever of the looms themselves.

The drawings of Egyptian looms (figs. 10, 11, and 12) were made from wall paintings at Bene Hasan and Thebes in Upper Egypt.

Figure 10 is rather a puzzling one, because the artist has combined a bird's-eye view of the loom with a side elevation of the weaver. The warp, which is a short one, is simply stretched upon the ground. There are no rollers or loom frame of any kind. The weaver is making a carpet or mat, it may be of rushes or grass. The only distinct facts to be gathered from this drawing are that the weft is being beaten down and the web is growing upward; also that the warp is fixed at both top and bottom.

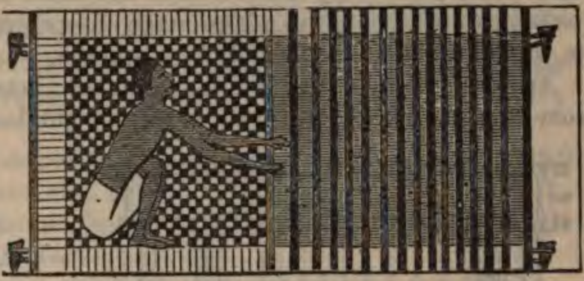

FIG. 10.—Egyptian loom and weaver.

In figure 11 two weavers work at a small upright loom. The weaver to the right is inserting a stick, with a hook at the end, into the warp. This hooked stick has been the subject of much discussion, but I believe it is really a spindle with the weft wound on it, the artist not being able or not having troubled to indicate the thread. Possibly he was an ancient post impressionist, and only represented symbols and souls of things, not their actual appearance or sordid detail.

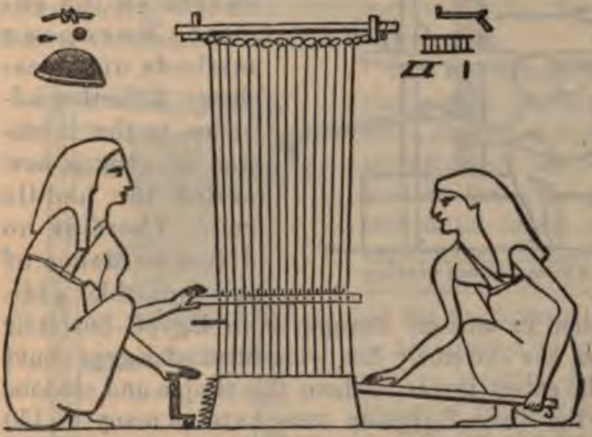

FIG. 11.—Egyptian loom in use.

The weaver on the left is evidently preparing to beat the weft together with the comb which is ready to descend upon it as soon as it is inserted. Here, again, the warp is fastened at the top and bottom of the loom, and the web is growing upward. As the loom has no rollers either at the top or bottom, only a loom's length of material can be woven on it.

Figure 12 is a much more effective-looking loom than either of the foregoing, although there are many puzzling points about it. It has loom posts, and is evidently a solid structure. There are no rollers definitely shown, but they may well be there. The arrangement of sticks at the top may be intended to represent a skeleton roller, and the bottom one on which the cloth is wound as it is made may be hidden by the bench on which the very active weaver, wielding the hooked stick, is at work. The cross sticks are shown, but their pu pose could never be detected from the picture. There is not muc indication—only a line—as to which is woven web and which unwoven warp. I imagine the line just above the weaver's knee is that of the already woven portion, and that all above is unwoven warp. Also that the line by the weaver's left hand indicates where he is picking up alternate threads to make an opening for the weft which is wound upon the hooked stick or spindle.

Anyhow, we have here the warp stretched between the top and bottom bars, or probably rollers, of an upright loom of solid construction at which the weaver is at work in such a position that he must be beating the weft downward, and the web be growing upward.

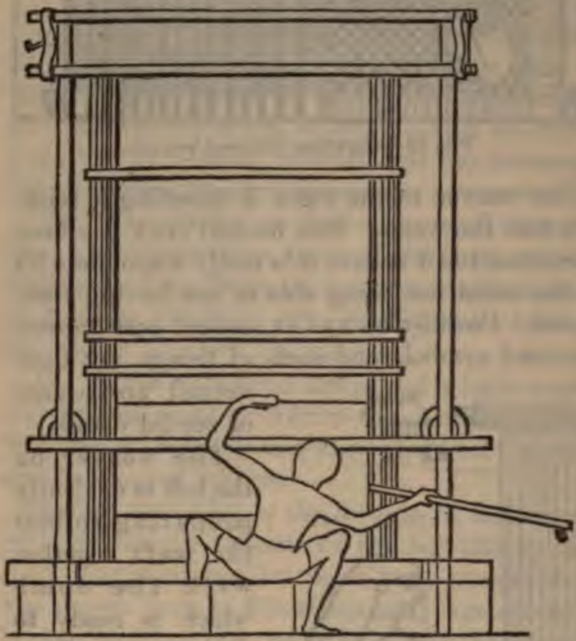

FIG. 12.—Egyptian loom for linen weaving.

Fastening the warp at both ends to rollers and weaving upward are without doubt great advances on the ancient European methods of procedure. A further advance is the invention of what is now called the heddle rod. There is no direct evidence of this valuable addition to the loom either in ancient Europe or in Egypt, but it is difficult to believe that the extremely fine wide linen of Egypt could have been woven to the extent it was, without this simple and obvious appliance. Some of the finest Egyptian webs have as many as 150 threads of warp to every inch of their width, and it seems incredible that this multitude of fine threads could have been profitably manipulated with the fingers only.

It is possible that the bar across the loom (fig. 12), on which the weaver is apparently only resting his arm, may be a heddle rod. This important appliance I must now explain.

Returning for a moment to figure 3, let me call your attention to the loose loops which I pointed out as time economizers, but did not further describe.

These loose loops are attached one to each thread of the warp, which is at the back of the lower cross stick. The cross stick makes one shed or opening for the weft. The loops, on being pulled forward, bring the back threads to the front, and so make the second or alternate opening.

You will see this at once if I add loops to my simple loom and insert a rod to enable me to raise them all together.

[Here the lecturer demonstrated the use of the heddle rod (fig. 13).]

As an appliance for two important branches of textile work—tapestry weaving and the weaving of hand-knotted pile carpets—the loom, at the point we have now reached, seems to be capable of no further development.

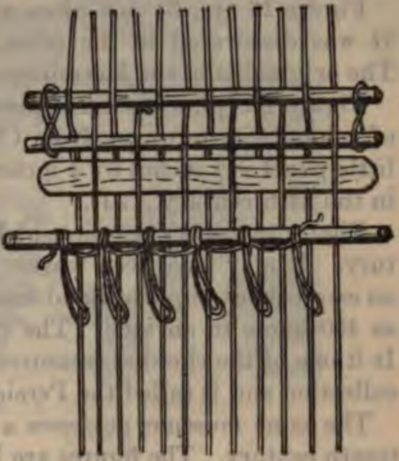

FIG. 13.—Loops and heddle rod.

Figure 14 is a design for a small tapestry loom from Mrs. Christie's "Handbook of Embroidery and Tapestry Weaving."[1]

This loom, simple as it is, can not be improved in its mechanism, except perhaps in some unimportant details, for the use of the artist weaver to work out his free designs upon.

All the gorgeous and more or less elaborately ornamented carpets of the East, as well as the exquisitely wrought tapestries of the West, from the most ancient times to our own, have been woven on looms of no more complicated construction than this. Added mechanical contrivances limit the scope of the craftsman. Freedom of design is trammeled in proportion to the facilities invented for the automatic repetition of pattern in the loom.

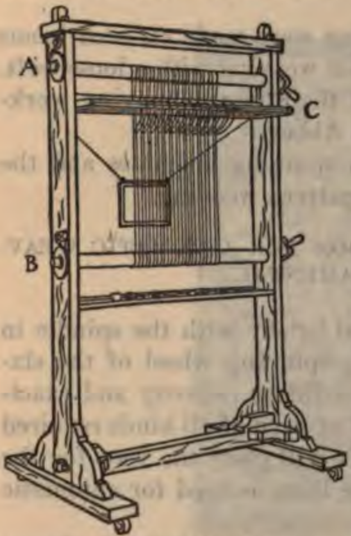

FIG. 14.—Tapestry loom.

The six illustrations with which I conclude this lecture are taken from the masterpieces of weaving made on looms of no more elaborate construction than figure 14 at different periods by equally skilled craftsmen in various parts of the world.

Figure 15 (pl. 3) is the most ancient piece of ornamental tapestry weaving known to exist. It is extremely fine in texture, the whole piece being only 4 inches by 1¼ inches in size. It formed part of the robe of Amenhilep III, who reigned in Egypt 2000 B. C. The original is in the Cairo Museum.

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[1] "Handbook of embroidery and tapestry weaving," John Hogg, Paternoster Row.

Figure 16 (pl. 3) is a piece of Greek tapestry of about 500 B. C. It was discovered in the relics of a Greek colony in the Crimea. The original is in the Hermitage Museum, St. Petersburg.

Figure 17 (pl. 3) is a fine piece of Egypto-Roman tapestry woven of colored silk unwoven from Chinese webs. The actual size of the little panel is 4 inches by 4 inches. It formed part of a child's tunic in the fifth century A. D.

Figure 18 (pl. 4) is a piece of Persian weaving of the sixteenth century. It may have been woven in Venice by Persian weavers. It is an exquisite example of hand-knotted velvet pile, there being as many as 400 knots to an inch. The color and ornamentation are superb. It it one of the choicest treasures of the Victoria and Albert Museum collection and is called the Persian cope.

The same museum possesses a set of Brussels tapestry of the sixteenth century. The figures are life size and are splendidly wrought. Figure 19 (pl. 4) represents a portion of one of the panels.

The subject of figure 20 (pl. 5) is a modern tapestry by Morris & Co. The design, "The Passing of Venus," was made by the late Sir E. Burne-Jones. The tapestry took seven years to produce and, being sent to the recent Brussels Exhibition, was destroyed in the disastrous fire which took place there, together with many other art treasures.

All these examples of tapestry weaving were made on such looms as figure 14 and are really mosaics of plain weaving with a loose weft.

Figure 21 (pl. 6) is a photograph of the tapestry-weaving workshop of Messrs. Morris & Co., at Merton Abbey.

In the next lecture I shall deal with spinning machines and the development of the loom for automatic pattern weaving.

II. SPINNING MECHANISM AND THE LOOM FOR AUTOMATIC WEAVING, PLAIN AND ORNAMENTAL.

In the present lecture I shall first deal briefly with the spindle in its later development from the domestic spinning wheel of the sixteenth century to the machines of extraordinary capacity and exactness which supply the enormous quantity of yarn of all kinds required in the textile industries of to-day. This will clear the way for the further and more important study of the loom as used for automatic plain and ornamental weaving.

On the primitive spinning wheel, you will remember, I pointed out that the spinning of the thread and winding it on to the spindle were separate alternate operations. On the more modern spinning wheels the spinning and winding are made simultaneous by means

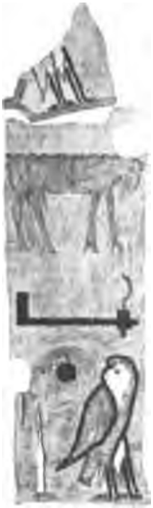

FIG. 15.—EGYPTIAN TAPESTRY.
(Cairo Museum. 2000 B. C.)

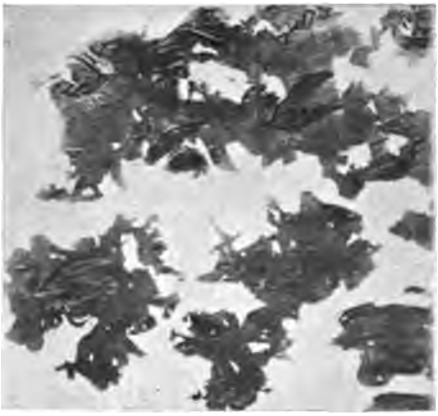

FIG. 16.—GREEK TAPESTRY.
(500 B. C.)

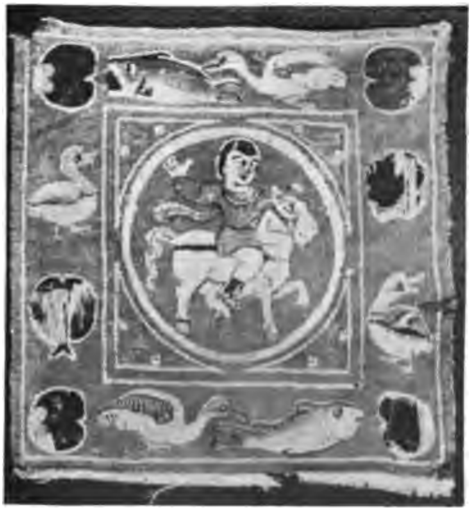

FIG. 17.—EGYPTO-ROMAN TAPESTRY PANEL.
(Victoria and Albert Museum.)

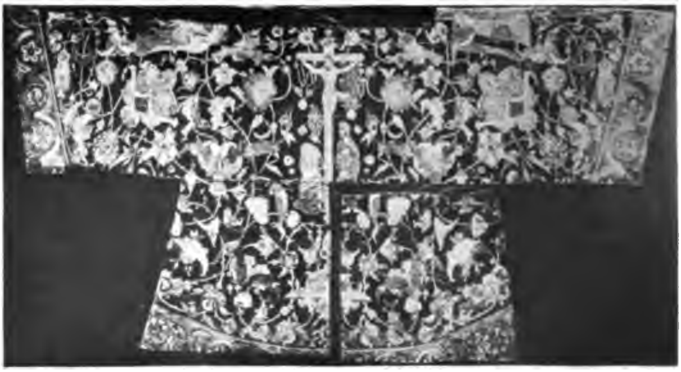

FIG. 18.—THE PERSIAN COPE.

(Victoria and Albert Museum.)

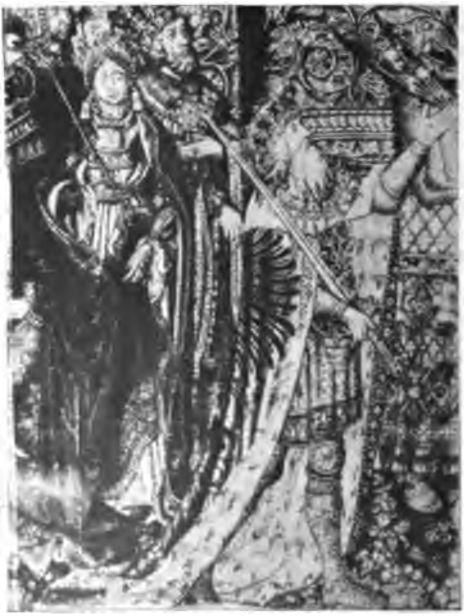

FIG. 19.—PORTION OF A BRUSSELS TAPESTRY.

(Victoria and Albert Museum.)

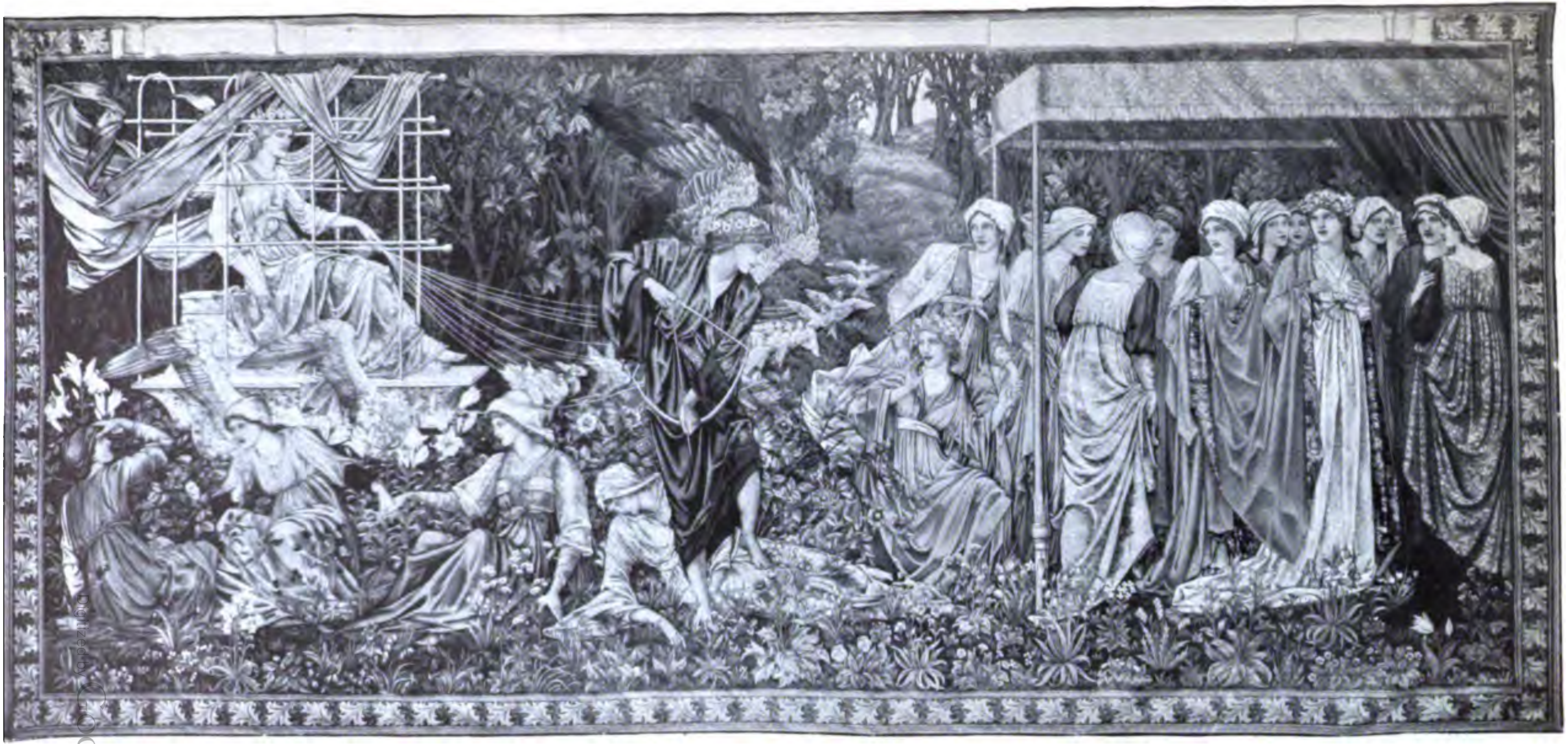

FIG. 20.—"THE PASSING OF VENUS." MORRIS TAPESTRY.

(Designed by the late Sir E. Burne-Jones.)

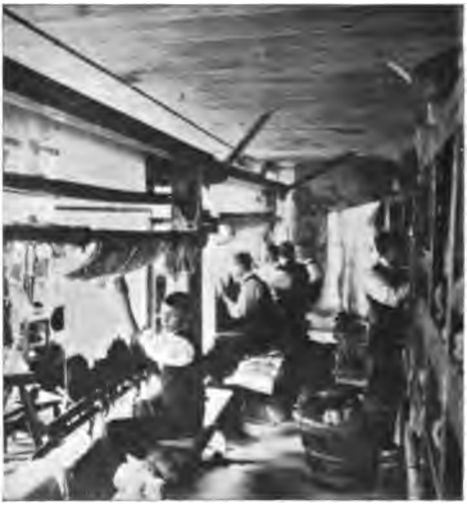

Fig. 21.—Tapestry Weaving in the Merton Abbey Factory of Messrs. Morris & Co.

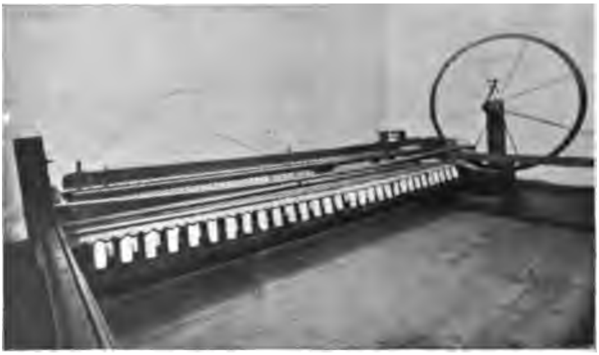

Fig. 23.—Hargreave's Spinning Jenny.

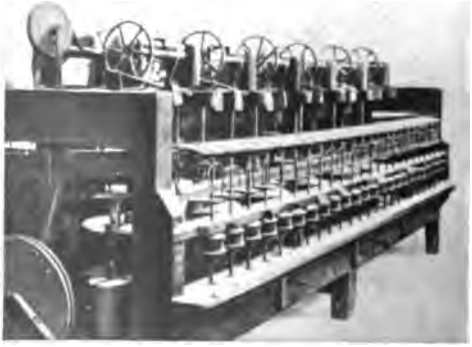

Fig. 24.—Arkwright's Water Frame.

of a little contrivance called a flier and bobbin attachment to the spindle.

The first historic hint we have of this invention is from a drawing in one of the sketchbooks of the great artist-craftsman, Leonardo da Vinci. But it was not until nearly a century after his death, which took place in 1519, that the spinning wheel with this clever attachment came into general use.

Figure 22 shows Leonardo's drawing and the later spinning-machine attachments which have been derived from it.

In Leonardo's drawing No. 1 is called the flier. It is firmly fixed on the end of a shaft or spindle No. 2 A and 2 B. No. 3 is a small pulley also firmly fixed to the spindle between the bearings C and D. When this pulley is made to revolve very rapidly, by means of a cord or belt from a large wheel, the flier revolves with it and twists the thread which is passed through the hole in the spindle at No. 2 A.

No. 4 is another pulley, rather larger than No. 3. This pulley is fixed on a hollow shaft, which extends from the pulley to No. 5. In the hollow of this shaft the spindle can freely revolve, and on it the bobbin, No. 6, tightly fits.

Now, if the different-sized pulleys, Nos. 3 and 4, be actuated by cords from the same large wheel, the flier will revolve at a greater speed than the bobbin, the difference in speed being, of course, in proportion to the difference in size of the pulleys.

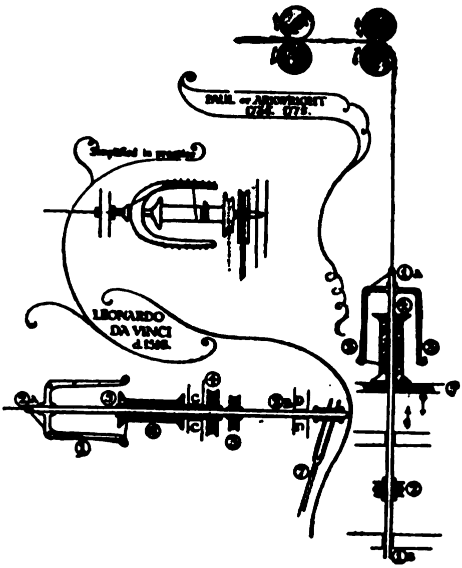

FIG. 22.—First drawing of bobbin and their attachment for spinning wheels.

The result of this arrangement will be that, if the thread, twisted by the revolution of the spindle, be passed through the eyes in the flier, as in the drawing, and fastened to the bobbin, two operations will take place: (1) The thread will be twisted by the flier; (2) because the bobbin revolves at less speed than the flier the thread will be gradually wound upon the bobbin.

No. 7 appears to be a kind of fork fixed to the end of the spindle. If this fork were pushed to the right the eye of the flier could be placed at any part of the bobbin, so as to spread the yarn evenly upon it.

Sooner or later this suggestion of Leonardo's was practically adopted, and the spinning wheel, fitted with bobbin and flier, came into general use in Europe. The distaff and spindle, however, have not, even to this day, been altogether superseded.

A more compact and convenient contrivance for spreading the spun thread upon the bobbin is shown above Leonardo's sketch. In place of the fork for altering the relative position of the flier and bobbin, a row of small hooks is placed along the arm of the flier, by means of which the thread can be guided on to the bobbin at any part of its barrel. This is the twisting and winding arrangement with which the improved spinning wheels of the seventeenth century in Europe were fitted up.

In order to compare it with Leonardo's sketch I have to the right of it (fig. 22) made a diagram of the bobbin and flier of a machine spindle.

It is old-fashioned now, as a modification of it, called the ring spinner, has taken its place. The principle on which it works, however, is the same, so, as it is more convenient to compare with the original sketch, I prefer to use it.

Here Nos. 1 A and 1 B indicate the spindle, which is caused to revolve by the pulley, No. 2.

The machine spindle is fixed vertically, a hundred or two being ranged on one machine.

The flier, No. 3, is fixed at the top of the spindle.

No. 4 is the bobbin standing on a shelf, No. 5. The shelf is made to rise and fall automatically as the thread is delivered to it from the flier. This is, therefore, a return to Leonardo's idea of the shifting spindle.

The spindle passes through the bobbin, but there is no hollow shaft for causing the bobbin to revolve. It simply stands loosely on the shelf, and when the thread from the flier is attached to it, the revolving flier drags the bobbin round at a less speed than its own, the weight of the bobbin acting as a brake. The thread is thus wound on more or less quickly, according to the weight of the bobbin.

In the ring spinner before mentioned the bobbin, or paper cop, is fixed firmly on the spindle and the flier is free. The flier runs on a ring which encircles the cop and drags upon it. This acts in the same way, as to winding, but makes it possible for the spindle to revolve at a much higher speed.

Although thus adopted for machine spinning, the idea of a loose bobbin was not, I believe, a new one. Spinning wheels had probably been previously fitted with loose bobbins, such as that shown in the diagram, above Leonardo's drawing. In this case the fixed flier is revolved by a pulley, which is connected by a belt to a large wheel. The loose bobbin, if not heavy enough to act as its own brake, has a string which is lightly attached to some fixed part of the framework of the machine. This being passed over, the bobbin brake pulley can be easily made to regulate its drag to a nicety.

At the top of the diagram (fig. 22) are shown two pairs of rollers, between which the fibers to be spun are being drawn out with such regularity as few spinners could boast of. In a machine such rollers are set in a series, at very accurate distances apart, and revolved in the direction indicated by the arrows. The front pair of rollers revolve more quickly than the second pair; the second pair than the third, and so on. Consequently, as the fibers pass between the series, they are gradually drawn out into a fine fleecy rove which, between the front rollers and the spindle, becomes twisted into fine even thread.

This system of drawing out fibers by means of rollers was invented by Paul in 1735 and made practical by Arkwright in 1775, when he patented it. His right, however, was disputed, and on trial the patent was annulled, but his adaptation of the system was soon generally adopted.

When describing, in the last lecture, the primitive spinning wheel and the distaff and spindle, where the spinning and winding on were done alternately, I should perhaps have remarked that the finest threads were always produced in this manner. It is not surprising, therefore, that very early in the history of machine spinning it was found that very fine, delicate threads could not be spun on the simultaneous principle. To overcome this difficulty Crompton invented the mule machine, which imitates exactly the alternate twisting and winding of the primitive method of spinning. It was interesting to see at the Anglo-Japanese exhibition of 1909 the huge English machine of 250 spindles imitating with perfect precision the actions of a pretty girl in the Japanese handicraft section who was spinning gossamer thread on a primitive wheel, the same kind of wheel which had been in use in her country for a couple of thousand years or so, and which, we may hope, will be used for an indefinite number of thousands of years more by such charming little spinsters.

Messrs. Dobson & Barlow (Ltd.), of Bolton, have courteously sent me five photographs of spinning machinery of great interest, which will require little explanation.

Figure 23 (pl. 6) is Hargreave's spinning-jenny.

Figure 24 (pl. 6) is Arkwright's water frame, so called because he used water as a motive power to drive it. It combines the drawing rollers with the flier and bobbin attachment suggested by the spinning wheel then in general use.

Figure 25 (pl. 7) is Crompton's mule, which he used in secret for some time, and mystified his neighbors by the quantity and quality of the yarn he produced.

Figure 26 (pl. 7) is a full-sized mule spinning machine by Messrs. Dodson & Barlow (Ltd.), of Bolton, which works on the same principle as Crompton's mule and the Japanese girl I referred to just now.

Figure 27 (pl. 7) is a ring spinning machine, working on the principle of this Italian peasant spinning wheel—the driven bobbin and the loose flier.

[The lecturer here exhibited Italian and Belgian spinning wheels, having a driven bobbin and a loose flier, and demonstrated how similar effects were obtained (1) by a separately driven bobbin and flier, (2) a driven flier and loose bobbin, and (3) by means of a driven bobbin and a loose flier.]

In conclusion, as regards the spindle, although we may congratulate ourselves on the performances of these wonderful thread-making machines and admire the inventive genius which has brought them to such perfection, it is interesting, though perhaps chastening and humiliating, to note that the untutored Hindoo spinner, squatting on the ground with a simple toylike spindle, can draw out and spin thread as fine, but infinitely stronger, than the most perfect machine of them all.

I now resume the inquiry as to the development of the automatic loom from the point arrived at at the end of my last lecture.

Four thousand years ago, more or less, probably at the time when the people of the stone age in Europe were cultivating flax and spinning and weaving its fiber into coarse cloth, the Chinese were inventing improvements in their primitive weaving appliances in order to adapt them to the weaving of an infinitely finer fiber than that of flax. This fiber was obtained by unwinding the case of the chrysalis of the mulberry-feeding moth, the caterpillar of which is familiarly known as the silkworm.

Chinese continuous written history goes back to that remote period, and tells that the annual festivals of agriculture and sericulture, which are still observed by the Chinese, were instituted by an Emperor and his wife, who themselves took leading parts in the festival, the Emperor plowing a furrow and the Empress unwinding some silkworm cocoons. This practice their successors have continued to the present time.

This Empress is still highly honored in China, and votive offerings are made to her at the festival. She is held in great regard as the benefactress who taught the Chinese how to prepare the silken thread for use and to weave it, thus enabling them to become the best and richest clothed people in the world. This preeminence they have maintained owing to their original monopoly and expert knowledge of the cultivation and manipulation of the strongest, finest, and most lustrous of all threads now called silk.

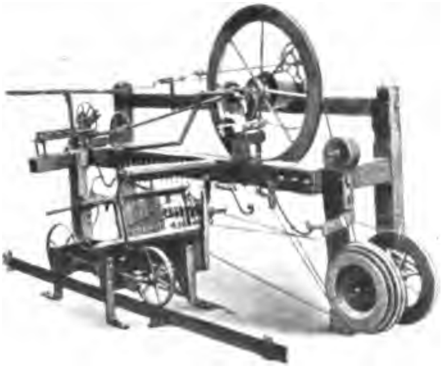

FIG. 25.—CROMPTON'S MULE.
(Bolton Museum.)

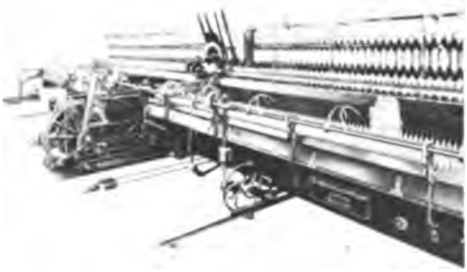

FIG. 26.—MODERN SPINNING MULE.
(Dobson & Barlow, Ltd.)

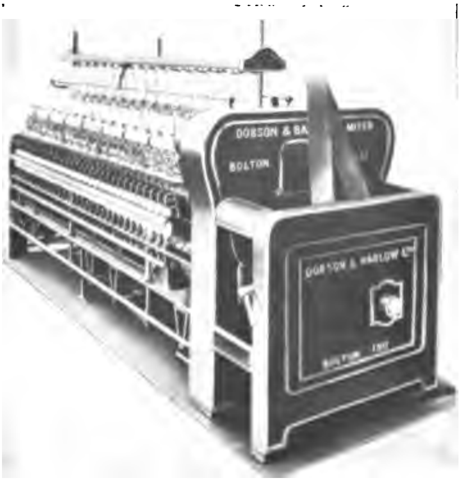

FIG. 27.—RING-SPINNING MACHINE.
(Dobson & Barlow, Ltd.)

The silk fiber, on being unwound from the cocoon, is found to be a continuous, double thread of about the four-thousandth part of an inch in diameter. It takes from eighty to a hundred threads of natural silk to make up one thread of the size of the finest spun flax. It may be well understood, therefore, that special preparation of silk thread and specially delicate appliances are necessary for weaving it. This necessity proved to be, as is proverbially the case, the mother of many inventions, and there can be no doubt it is from the original Chinese weaving appliances that almost all succeeding improvements in looms and loom fittings have been derived.

In order to describe the improvements in the loom required for weaving fine silk, reference must be made to figure 28, which shows a primitive loom fitted with a heddle rod for the purpose of raising the threads of the warp alternately with those raised by the shed stick.

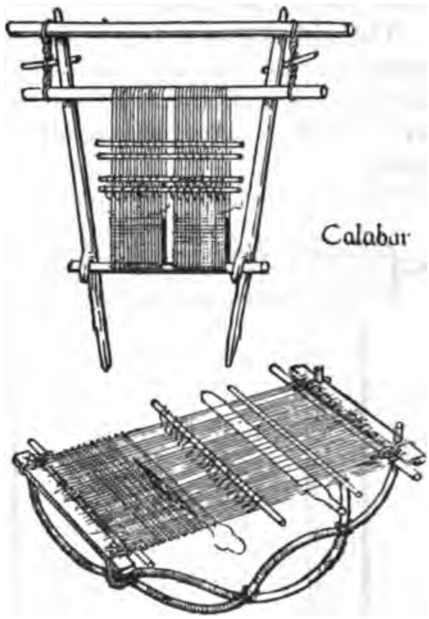

Fig. 28.—Primitive looms. (One fitted with two heddle rods.)

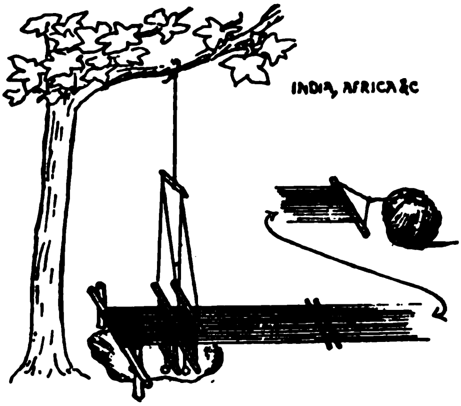

Fig. 29.—Primitive loom (India, etc.).

Two heddle rods in an upright loom would be no great, if any, advantage; but if the warp be placed horizontally, the manipulation of the successive openings for the weft is much more convenient for the weaver, who sits at the end of the warp instead of in front of it.

Figure 29 shows a very convenient form of Indian loom with the heddle rods suspended from the branch of a tree and having the heddle loops connected with another pair of rods beneath the warp. The lower rods have strings hanging from them, each terminating in a ring. By placing one of his great toes in each ring the weaver can pull down either set of loops at will and make alternate openings for the shuttle carrying the weft. His hands are thus left free to manipulate the shuttle.

The addition of a long comb, equal in length to the width of the warp, was an immense improvement to the loom. The divisions in it were originally made of split reeds, hence it was called the reed, and is still so called, although the divisions are now always made of steel.

The effect of the long comb, with the warp threads entered in it, swinging in its heavy frame (see fig. 30), was not only that the weft was beaten together more evenly and with less individual strain on the threads, but the width of the woven web was kept automatically the same.

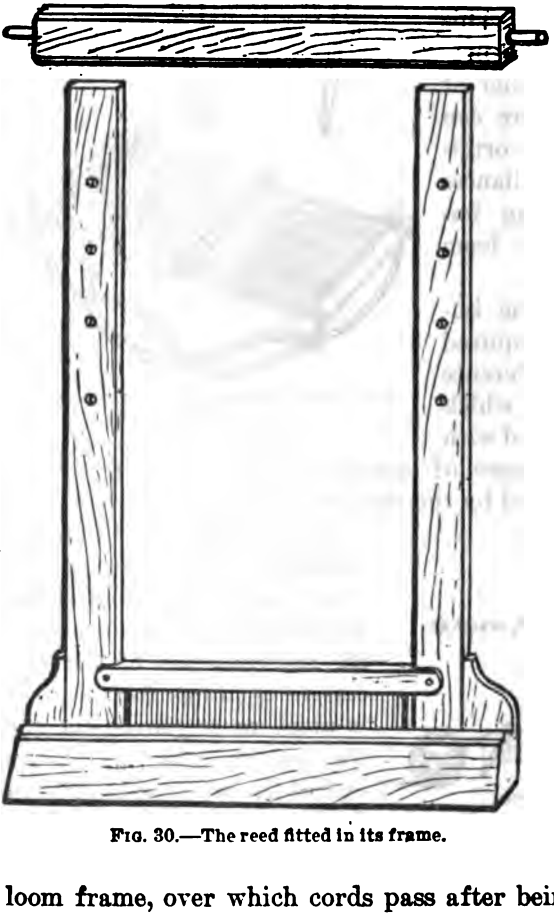
FIG. 30.—The reed fitted in its frame.

Figure 31 is a longitudinal section of the essential parts of a loom at the point of development now arrived at. It is lettered for reference. A is the roller on which the warp is wound in the first instance. B is the roller onto which the woven cloth passes. C C are the sticks preserving the cross which keeps the warp in order. D is one of two pulleys suspended from the top of the loom frame, over which cords pass after being attached to the ends of the top laths of the two heddles. At E are two treadles which are tied to the lower laths of the heddles. Between the heddles and B the reed is shown suspended.

One treadle is represented depressed. This has pulled down one heddle and raised the other in consequence of the cord which passes over the pulley D. This movement has effected an opening in the warp at F, which between the roller B and the reed is wide enough for passing the weft through.

The successful weaving of plain silk necessitates a development of the loom to this point. It is therefore reasonable to credit the Chinese, who until the third century A. D. were the monopolists of silk and silk weaving, with all these essential contrivances. Subsequently to the third century these inventions spread through the East generally and finally to Europe, first to Spain and Italy, then to France, Germany, and England. It is remarkable that the loom of to-day, on which the very best silk fabrics are woven, should in all essential points be the same as the looms of ancient China.

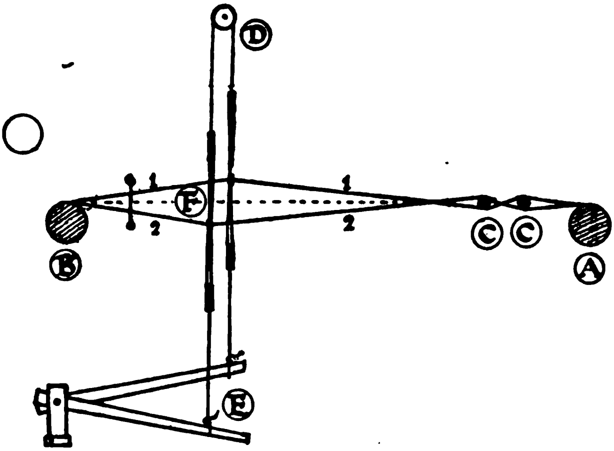

FIG. 31.—Section of opened warp.

Figure 32 (pl. 8) is from a sketch I drew from life in a Bethnal Green silk weaver's workshop a few weeks ago. The weaveress is making a rich black satin, which will be all but perfect when it is cut out of the loom, and will require no after artificial finishing to make it ready for sale. The loom is arranged in the simple manner described, except that as the weaving of satin requires more heddles than plain silk eight heddles instead of two only are shown.

The first impression given by figure 33, which is a diagram of an English loom, is one of sturdy strength. Strength and the perfect adjustment of the various parts of the loom are prime requisites where rapid and accurate weaving are desired.

Figure 34 (pl. 8) is from a manuscript of the fourteenth century and represents an English silk weaver of the period at his loom. Whether the weaver is in correct costume I can not say, but the loom and its fittings are quite recognizable and like the loom of to-day, except for their slightness.

Figure 35 (pl. 9) is from a very old Chinese drawing. It is one of a set of pictures representing the operations of sericulture. The first edition of the book from which it is taken is said to be of the twelfth century A. D.

It is the representation of a very perfect hand loom for silk weaving. The weaver is shown sitting on the edge of a square hole in the ground, in which a set of treadles are seen. The framework of the loom is very carefully and solidly constructed. The front or cloth beam is shown with the reed hanging freely between it and the heddles. The back, or warp beam, is out of the picture, and the warp slants toward it after passing through the reed and heddles. The heddles themselves are very carefully fitted up and are worked by means of the treadles in the pit, which are connected by cords to levers. These levers may be seen at the top of the picture.

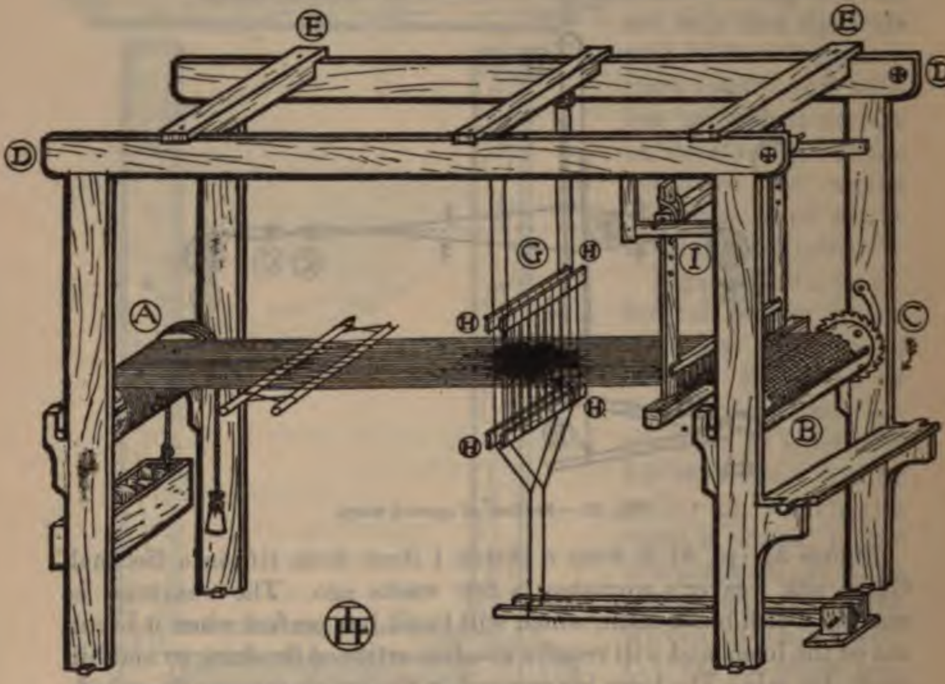

FIG. 33.—Typical English hand loom.

The weaver, sitting in front of the loom, has just, by a blow of the reed, beaten up the weft and is preparing to open the next shed and throw the shuttle which he holds ready in his right hand.

It will at once be noticed that the Chinese loom (fig. 35, pl. 9) has several heddles, instead of only two shown in the English loom (fig. 33). In fact, there are two sets of heddles working together, one set having 10 and the other 5 heddles.

The loom having two sets of heddles shows that some kind of pattern is being woven. As, however, at present I am speaking of the loom for plain or satin weaving, the second set of heddles need not concern us.

When the warp threads are very coarse and few in number, two heddles are sufficient for threading the warp, but when fine silk fabrics are to be woven, having three or four hundred threads to an inch, it is necessary to have several pairs of heddles in order to prevent the leashes, through which the silk is threaded, from being too crowded. In this Chinese loom the front harness, as a collection of heddles is called, consists of 10 separate heddles. In all looms the threads of the warp are passed through the eyes in the leashes of the heddles in regular order.

The first thread is passed through the first leash of the first heddle, the second thread through the first leash of the second heddle, then through the first of the third, and so on until all are filled.

[The lecturer here drew a diagram on the blackboard illustrating the method of entering a warp in the harness.]

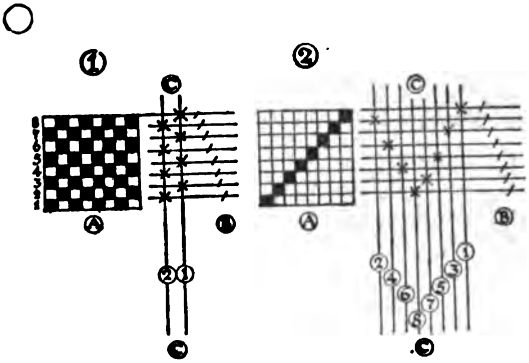

FIG. 36.—Plans of tie-up.

To manage this set of 10, or any even number of heddles, only 2 treadles are necessary for plain or tabby weaving. The heddles are first joined together in pairs at the top, each pair having its two separate pulleys, as in the typical English loom. (Fig. 33.) The bottom laths of the first, third, fifth, seventh, and ninth heddles are then all connected with one treadle, and those of the second, fourth, sixth, eighth, and tenth heddles are joined to the other treadle.

Now, it is manifest that if the first treadle be depressed half the warp, consisting of the first and all the odd-numbered threads, will be drawn down and the second and all the even-numbered threads will be drawn up. This will make the same opening for the weft as if there were only 2 instead of 10 heddles.

In order to make this quite clear, the plan and tie-up of the pattern, as it is called, is given at figure 36.

This arrangement being at first made for plain tabby weaving of a close warp of fine threads, it would soon be discovered that by increasing the number of treadles and tying them to the heddles in different ways the interlacements of warp and weft might be varied to an astonishing extent and result in the production of an infinite variety of small patterns.

Figure 37 gives, for example, four designs, which can be made on a loom fitted with four heddles and four treadles. If the threads of warp and weft are coarse enough, and the former white and the latter black, the designs would show as distinctly when woven as they do drawn out in the diagram.

There is not time, nor is it indeed necessary for our present purpose, to describe the way in which these designs are formed. All that is required is to note their possibility and to show how this possibility affected the development of the loom itself.

A further examination of this ancient Chinese loom will show that not only are there more than two treadles in use, but instead of the heddles being tied together in pairs, as for plain weaving, each heddle is connected with one of a set of levers which in their turn are joined by a cord to the treadles.

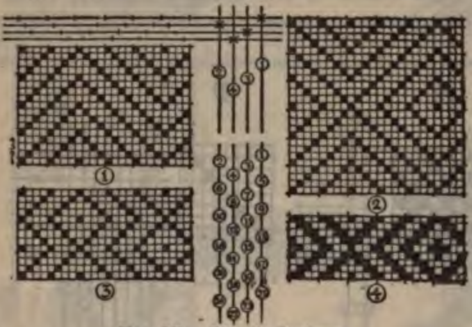

FIG. 37.—Simple designs.

Figure 38 represents, without other details of the loom, two typical shedding motions, as any arrangement for opening the shed for the weft is called. In both these motions, as in the Chinese loom, the arrangement is one of heddles, levers, and treadles connected together by cords. Below each diagram a longitudinal section of a loom at work is shown.

It is interesting to note that these ancient shedding motions are still in use. Silk fabrics made on hand looms fitted with these motions can not be equaled by webs woven on any machine loom yet invented.

Figure 39 (pl. 9) which I drew from a Bethnal Green workshop, as it now is, shows a silk loom with precisely the same fitting up as the Chinese artist has drawn.

To return to the shedding motions (fig. 38), in the right-hand figure the heddles A A have lead weights, B B, on their lower shafts. If, therefore, any of the four heddles be raised, as soon as they are released the weights will bring them down to their normal position. At the top of the loom, letter C, four short strong levers are fixed on an iron rod, which passes through a hole in their centers. From one end of each of these levers a heddle is suspended; and from the other end a cord hangs and connects each short lever with a long

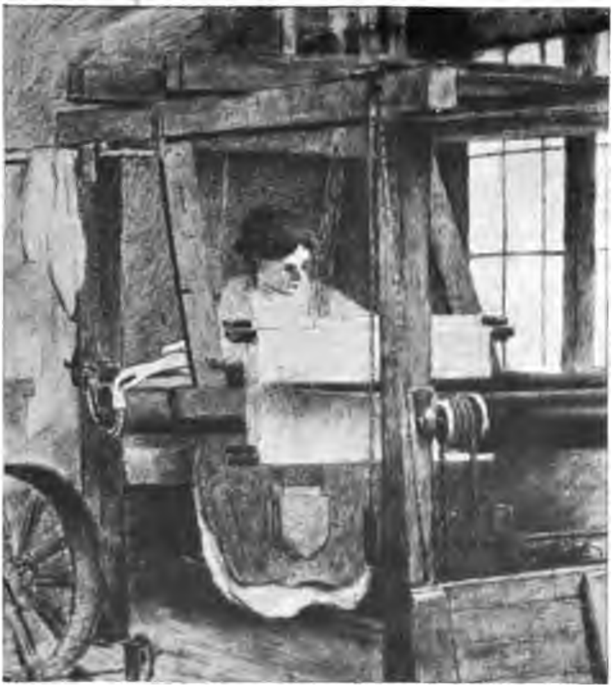

FIG. 32.—BETHNAL GREEN SILK WEAVER.

(From a drawing by the author.)

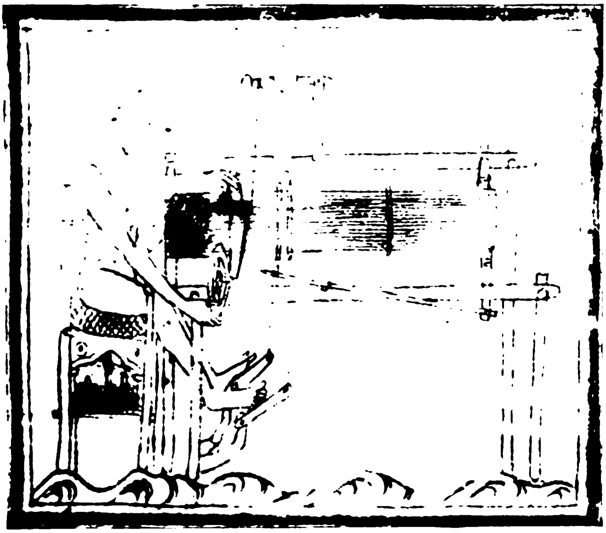

FIG. 34.—ENGLISH SILK WEAVER, FOURTEENTH CENTURY.

(From an old manuscript.)

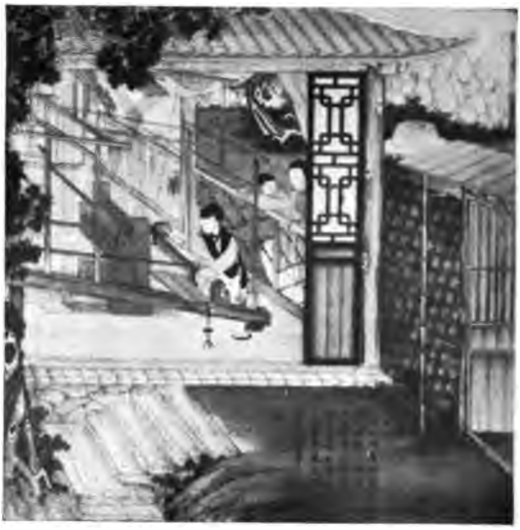

FIG. 35.—CHINESE SILK-WEAVER'S LOOM.

(Ancient Chinese drawing.)

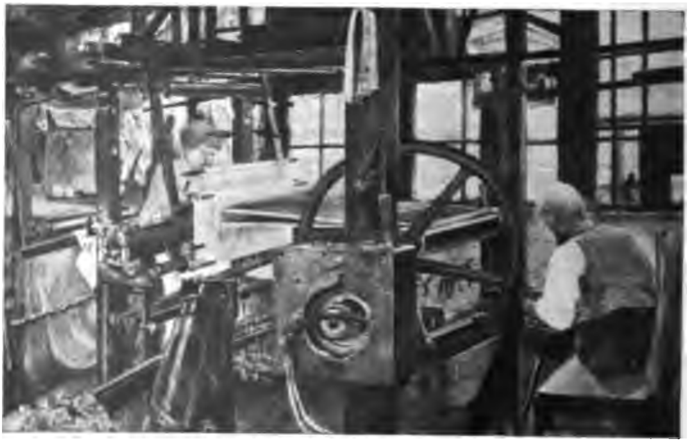

FIG. 39.—BETHNAL GREEN WEAVING SHOP, 1911.

(From a drawing by the author.)

one, D D, which hangs across the loom below the heddles and above the treadles, which are lettered E.

It will now be seen that if any one or more of the long levers be tied to any one of the treadles, the weaver sitting in the loom has only to select and press a treadle in order to raise any arranged combination of warp threads for the weft to pass under as it is carried by the shuttle through the opened shed.

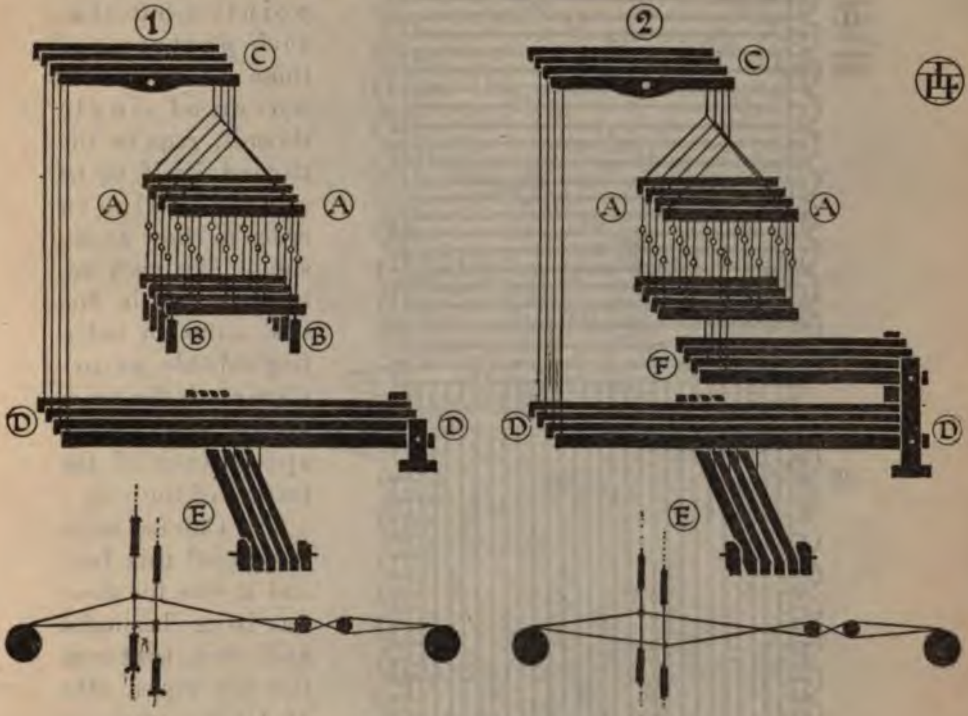

FIG. 38.—Shedding motions.

The character of the shed made by this motion is shown above. The horizontal line is the normal position of the warp. The opening is made by raising certain selected threads.

An examination of the section below No. 2 will show that in it not only are certain threads of the warp raised, but all others are lowered, and the horizontal line of warp has disappeared. This is effected by adding to the motion another set of short levers, marked "F," between the long ones and the heddles, and connecting the lower shafts of the heddles with them after removing the weights. If, now, for example, the first thread be required to rise and the second, third, and fourth threads to sink, the first treadle will be tied to the first long lever, and also to the second, third, and fourth short levers. The result of this will be that when the treadle is depressed the first heddle will be raised and the second, third, and fourth heddles will sink, thus making the required shed.

These are typical shedding motions. All other motions are based on one kind or the other of these types, each kind having its advantages for certain classes of weaving.

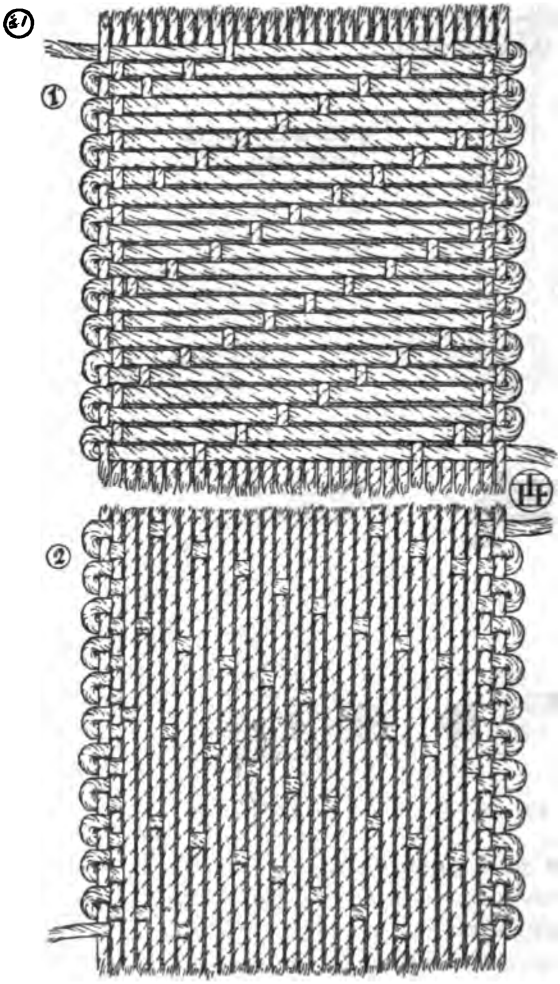

Fig. 40.—Satin cloth (much enlarged).

I have already pointed out that such patterns as those of figure 37, woven of single threads, require the thread itself to be coarse in size in order to show as designs. But such designs, woven in fine silk, although indistinguishable as ornament, have a marked effect on the appearance of the texture of the web.

The Chinese early discovered this fact, and it was for their various beautiful and rich textures that the woven silks of China were so much prized in classic times.

Figure 40 represents the back and front surfaces of a square of silk textile, which might have been woven in ancient China on a loom fitted up as I have described. It would require 16 heddles and 16 treadles to weave it, and the threads are so fine and lie so closely that the whole piece shown would be only the one-thousandth part of a square inch in size.

Looking at the lower square, which is the front of the material, it will be seen that the surface is nearly all warp, and that the intersections of the weft only occur at intervals of 16 spaces each way. In cloth of this pattern the intersections of the weft are invisible; therefore its whole surface has the rich texture and glossy appearance known as satin. In the same proportion as the front of the satin web is nearly all warp, the back, of course, displays the weft. In pattern weaving these effects are called, respectively, warp satins and weft satins.

Satins may be made on different numbers of heddles, from 5 up to 24. Figure 41 shows several of them drafted on designers' ruled paper.

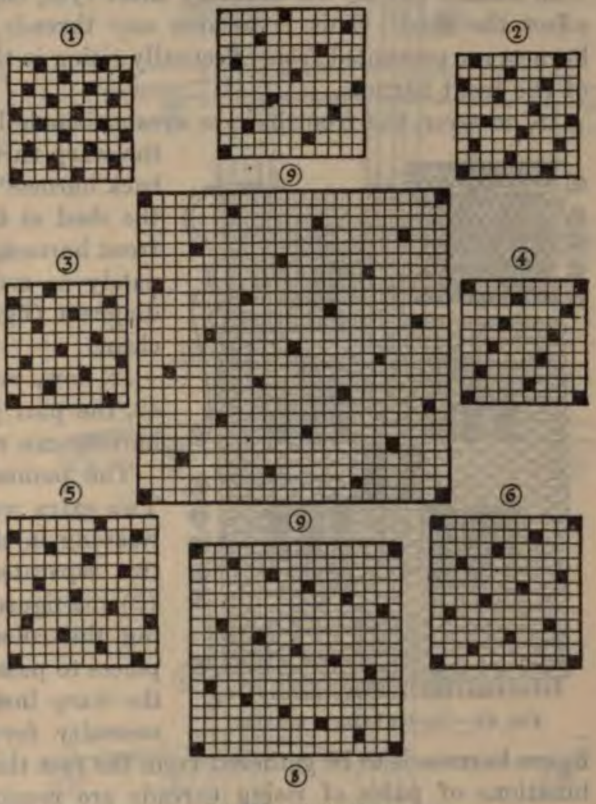

Fig. 41.—Satin ties.

The next step in the evolution of the loom was to adapt it for distinct pattern weaving. This was effected by adding a second set of heddles to the harness, making it what is called a compound harness.

This compound mounting is shown in the Chinese drawing. The front set of 10 heddles is for making the groundwork of the fabric, and the back set of five is for raising the figure, as the design is usually called in weaving.

Here is a very simple figure (fig. 42), which will well illustrate the method of double harness pattern weaving. It is of a kind, too, of which the Chinese are very fond, having spots of ornamental shape powdered over a plain ground. Moreover, it could be woven on a loom fitted up exactly as in the Chinese picture.

The ground of this design is a plain tabby silk. I have already shown how this can be woven in a harness of 10 heddles by means of 2 treadles. Five other treadles would, however, have to be added in order to work the figure harness, one for each heddle.

For double harness weaving, too, the leashes of the heddles of the front harness have an important peculiarity which must be described; for, though simple, it plays a most essential part in all pattern weaving with compound harness.

In this class of weaving each warp thread passes first through the eyes of the figure harness and then through those of the front harness, which makes the ground. Now, if both harnesses are alike fitted with leashes having the ordinary short eyes, only the front one can affect the shed. This is because any threads raised by the back harness are prevented from effectually rising in the reed by the leashes of the front harness.

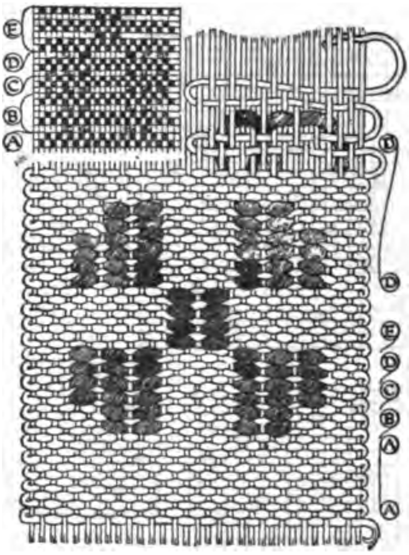

Fig. 42.—Double harness weaving.

If, however, the front harness eyes are made long enough to allow the warp threads to be lifted, the back harness will be free to affect the shed at the same time as the front harness, or to affect it alternately as may be required. The diagram (fig. 43) will make this clear.

If, now, we turn again to figure 42, the part played by the figure harness can readily be explained.

The points to notice are: (1) Two extra wefts are required for weaving in the design which has two separate colors of its own; (2) the figure is formed by allowing the colored weft in certain places to pass over two threads of the warp instead of one; (3) the necessity for five heddles in the figure harness is to be gathered from the fact that five different combinations of pairs of rising threads are required to complete the design; (4) as the figure throughout is made by two threads rising together, two threads together may be entered in each eye of the figure harness.

If this explanation is clear, it is only necessary to add that in silk weaving not only 2, but sometimes as many as 20, warp threads are entered in each leash eye of the figure harness. Therefore, it is evident that the possible scale of ornamentation and scope for the designer are immensely increased. For instance, this figure woven on two threads, as explained, on a fine silk warp of 400 threads to an inch, would only occupy the sixteenth of an inch in width and height, but if 20 threads were entered together in each leash eye of the figure harness the size of the ornament would be increased 10 diameters and would occupy nearly a square inch of surface.

There is, therefore, represented in this old Chinese drawing (fig. 35, pl. 9) a very perfect loom for weaving small designs of simple construction. The limit of size and elaboration of the pattern in this kind of loom is, however, reached when the number of figure treadles and heddles becomes too great for practical use. There is no evidence of the Chinese having endeavored to weave with an elaborate system of heddles and treadles such as were ingeniously devised in England in the eighteenth century, but which, being very difficult to fit up and manage, were soon superseded.

Figure 44 (pl. 10), taken from the same Chinese book as the foregoing Chinese drawing, shows, in a compound loom, a figure harness of entirely different construction, which is evidently made on the same principles as the perfected European drawloom of the eighteenth century, on which were woven the most sumptuous and intricate webs which the weaver's art has ever produced. In this representation of a pattern weaving loom, instead of the small figure harness of five heddles, a large one of quite different build is shown. Over this harness an assistant weaver, perched aloft at the back of the loom, is presiding. He is, in fact, drawing up, according to an arranged plan, certain groups of threads required for the formation of a pattern. The all-important part of this picture is the portion of the loom over which the assistant weaver is presiding.

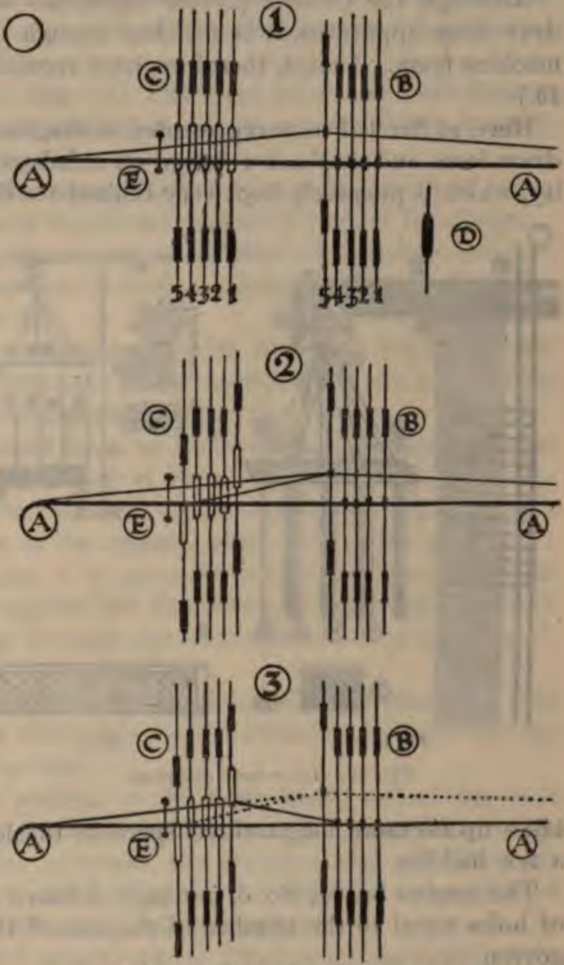

FIG. 43.—Double harness shed sections.

Taken by itself, it is a complete loom harness of remarkable capacity. In fact, for automatic pattern weaving, a loom fitted with this contrivance for raising the warp threads only is as complete in its way as the perfected primitive loom is for tapestry weaving, as I pointed out in the last lecture.

Although the Chinese picture represents what is unmistakably a draw-loom apparatus, it is not clear enough in detail to describe the machine from. I must, therefore, have recourse to a diagram. (Fig. 45.)

Here, at No. 1, I have represented in diagrammatic form the simple draw loom and at No. 2 a design on ruled paper suited to its capacity, which is purposely kept very limited for the sake of clearness.

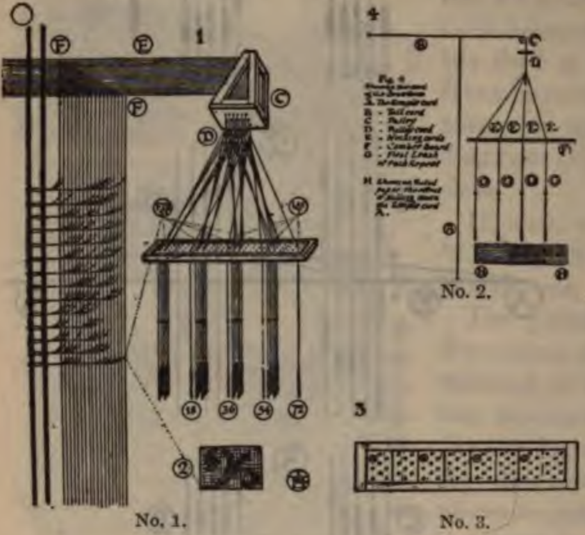

FIG. 45.—Draw-loom diagrams.

The whole mechanism of the draw loom centers in the comber board and leashes which hang in the loom in place of the ordinary harness of few or many heddles. The advantage of the comber board monture over the ordinary heddle harness is that whatever width a design may be, even to the whole extent of the warp, the monture takes up no more longitudinal space in the loom than a harness of a few heddles.

The comber board, No. 3, is simply a board pierced with a number of holes equal to the number of threads of the warp which it is to govern.

In each of these holes a separate leash is hung. Each leash has a long, thin lead weight at its bottom end; and in its center, instead of a string loop, a glass eye called a mail, through which a warp thread is entered.

The comber board in the diagram is only pierced with 72 holes; consequently it is only for a warp of 72 threads. If it were for 72,000 threads of fine silk, it would not take appreciably more space in the loom.

The drafted design at No. 2 is made on 18 lateral squares, so that it would repeat four times in the width of the web to be woven.

The word "comber" board is derived from an older word, "camber," which used to signify the repeats of a design as regards width. The board was called a camber board because the holes pierced in it were accurately apportioned to the number of threads in each pattern repeat, and the width of the total number of holes was the same as the width of the warp.

In this comber board (fig. 45) there are holes for four repeats of 18 leashes, but only six leashes of each repeat are shown in position, as more would confuse the drawing.

The bottom board of the triangular box C is pierced with 18 holes, the same number as that of the threads in each repeat of the design.

Let us suppose the comber board to be filled with leashes, one suspended in each hole; also that 18 cords are hanging through the holes in the triangular box at D.

The monture builder now connects, with fine cord, the first, nineteenth, thirty-seventh, and fifty-fifth leashes, which are the first in every repeat with the first hanging cord at D.

He next takes the second leash in each repeat, and connects it in like manner with the second cord at D.

He proceeds thus in regular order to connect leashes and top cords until he reaches the last of the repeats, leashes 18, 36, 54, and 72.

When this work is done it is apparent that if any one cord at D is drawn up into the triangular box the corresponding leashes in every repeat will be drawn up through the comber board to a corresponding height.

Moreover, if 72 threads of warp are entered in the leash eyes, the selected leashes as they rise will raise the threads necessary for the formation of the pattern shed.

This is the essential portion of the draw loom, and so far is it from being obsolete that all the pattern-weaving looms of to-day, whether worked by hand or power, are identical with it. Thus the immense textile industry of modern times is indebted to and linked with the invention and industry of ancient China.

Vast numbers of different methods of drawing up the cords of the loom were no doubt practiced in the East. Most frequently, as in the Chinese picture (fig. 44, pl. 10), the weaver's assistant who did this work sat above the loom drawing the cords line by line according to a written or painted draft.

There is no evidence to show what form this part of the loom had assumed when the art of silk pattern weaving was introduced into Sicily in the twelfth century. The rapid development of silk weaving in Sicily and Italy, which we know took place makes it more than probable that the convenient method of drawing the cords from the side of the loom, as shown in this diagram (fig. 45), was invented soon after the art was introduced. However, when introduced or by whom invented, it is certain that it was on looms mounted and fitted up in this manner that the masterpieces of the weaver's art, made in Europe from the thirteenth to the eighteenth centuries, were produced.

I resume the explanation of the diagram of the draw loom (fig. 45) at the point D, where the 18 cords are seen to enter the triangular box C. This box is fitted up with pulleys, 18 in number. Each cord passes over a pulley and is seen again at E. The collection of 18 cords, called the tail of the monture, is then securely fastened to the wall of the workshop, or some convenient strong post.

Between F and F another series of 18 cords, called the simple, is tied to the tail series and fastened to the ground.

A simplified diagram, showing one cord in all its parts, is given in No. 4.

Now, it will at once be seen that if the cord A be pulled down by an assistant standing at the side of the loom, the eyes of the leashes G, through which the warp threads pass, will be pulled up.

It is necessary, then, in the simple, to have as many cords as there are threads or groups of threads in each repeat of the comber board. And it is possible to weave on the loom any design, of whatever length, that can be drawn on the number of threads arranged for in each repeat.

If we turn to the design No. 2 we shall see that it is drawn on 18 squares, and if we compare the design with the loops tied from the large guiding cords to the separate cords of the simple, we shall see that they agree. The black squares in the design represent a tie. Take the first line, beginning at the left-hand side. Here are six black squares. If we follow the dotted line to the first cord of the simple, a group of six ties will be found. Then passing over six cords, a group of four ties are found which correspond with the four black squares in the third division of the sketch.

By means of these loops the drawboy, as he was called, selected the cords for pulling down, and, having gathered them together on the prong of a large fork, to which a lever was attached, he pulled the lever and drew the leashes up, thus opening the shed for the weaver's shuttle.

The design had to be tied up on the simple cords line by line before weaving could commence; but when this was once done the drawboy had only to pull the cords, in regular sequence, in order to repeat the design continuously in the length of the web.

On this mounting of the loom entered with single threads of warp any possible interlacements of warp and weft can be worked out. It may well be called, therefore, the most perfect loom. Its only limitation is in the size of the design. It would require a simple of 400 cords to tie up a design one inch wide for a silk web 400 threads to an inch.

This difficulty was surmounted by adopting the compound harness arrangement I have already described. It is shown in the Chinese drawing of the pattern-weaving loom (fig. 44, pl. 10).

If threads entered singly in the front harness are lifted in tens by each leash of the figure harness, the design will be woven 10 inches wide instead of 1 inch; the simple and tie-up being no more extensive or complicated.

More elaborate interlacements of warp and weft were arranged for by dividing the comber board into two or even three parts, each governed by a separate set of simple cords, as well as by adding more warps and rollers to the loom, and additional harnesses of heddles for binders and stripes of satin, tabby, or tobine effects. In fact, there seems to be no limit to the different combinations the skillful designer may invent and provide for in this most perfect and adaptable of all craftsman's tools, the compound draw loom.

In my third lecture I shall describe the Jacquard machine and some other important weaving inventions of the eighteenth century, the evolution of the power-driven loom, describe a new circular loom, and indicate some possible developments of the weaving machines of the future.

III. THE JACQUARD MACHINE; POWER-DRIVEN LOOM.

INTRODUCTION.

In the two previous lectures my chief aim has been to point out the traditional continuity of the art of weaving and to show that all real advances in it have been made by bringing new ideas to bear on old principles. This method of advance is common not only to the textile but to all the arts of life. Man, at his best, is not a creator, but an improver, and all attempts to break with tradition and to produce something quite original always must end in more or less grotesque failure.

I have tried to bring this truth out as regards the hand loom and spindle, and in the present lecture I shall chiefly direct your attention to the same fact, as exemplified in the development of the mechanism of the power loom during the last century.

THE MODERN LOOM FOR PLAIN AND ORNAMENTAL WEAVING AND ITS FUTURE DEVELOPMENT.

In the early part of the eighteenth century, weaving, as a handicraft, reached in Europe its point of highest perfection. France, England, and Italy were the chief countries in which it was practiced.

At that time, in England particularly, the condition of the textile craftsman, of whatever grade, seems to have been better than at any other period of which we have record.

The weaver of the eighteenth century was a prosperous and respectable tradesman, whether working in the secluded country village, in the suburbs of the great towns of the north and east, or near the metropolis in the pleasant district of Spitalfields, notable as the silk-weaving quarter of London.

This happy condition of the weaver in the eighteenth century declined to one of misery in the nineteenth. The economic causes of this change are not far to seek, but form not part of my subject. I only refer to this period of prosperity, as it marks an important stage and change of direction in the development of the loom.

Hitherto the motive of inventors was to increase the scope and perfection of the loom as a pattern-weaving tool. The perfection attained and the care bestowed on loom construction are shown in the beautiful illustrations of Diderot's Dictionary and other technical works of the period.

During the latter portion of the eighteenth century, and since, the chief purpose of invention has been, not excellence of work and extended capacity of the loom, but economy of time and cheapening of production.

The interesting business of weaving, from the tying up of the design to the picking and finishing of the woven cloth, which the weaver originally did himself, is now divided up amongst half a dozen "hands," who only do one particular portion of the work, and thus monotonously perform their daily task.

Not only is the weaver's work to a certain extent degraded, but the change from wood to iron for loom construction and the use of steam as a motive power, as well as the subdivision of labor, have necessitated the grouping of looms in large factories, with all their inconveniences and attendant evils.

This revolution of industry occupied more than a century and a half and was effected in some branches of the trade sooner than in others. The process is, in fact, in the best branches of silk weaving, still going on.

The first indication of the coming change in the broad-weaving trade was given as early as 1687, when Joseph Mason patented a machine which he described as "an engine by the help of which a weaver may performe the whole work of weaving such stuffe as the greate weaving trade of Norwich doth now depend on, without the help of a draught-boy, which engine hath been tryed and found out to be of greate use to the said weaving trade."

It is necessary to the understanding of the mechanism of the important machine which superseded it, which I shall presently fully describe, to have a general idea of this drawboy machine. In order to give this idea, however, I must first describe the work of the human drawboy. For the purpose we shall need the diagram of the draw loom (fig. 44, pl. 10).

[Here the lecturer again briefly repeated his explanation of the various parts of the draw loom.]

In a rich silk loom there were often as many as two or three thousand lead weights, called lingoes, hanging three to each leash of the monture. These weigh altogether a couple of hundredweight. On an average half of them had to be drawn up at every line of the design. Moreover, their dead weight would be so increased by the friction of the multitude of cords and pulleys that the boy would have to raise and hold for several seconds a weight equal to a hundredweight and a half. This would, of course, be impossible but for some mechanical help. The implement devised for the boy's assistance was called the "drawboy's fork." This is shown at figure 46. The vertical lines in this diagram represent the cords of the simple.

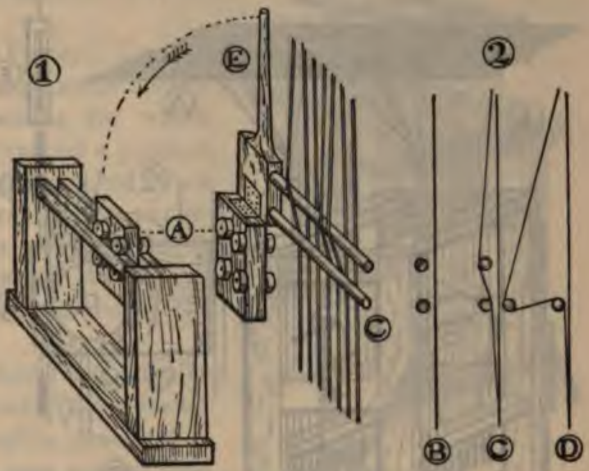

FIG. 46.—Drawboy's fork.

To the left is a solid stand having two broad uprights joined together at the top by two parallel bars. A is a block of hard wood, which fits between the bars, and is held in position by four pairs of small wheels. These not only support it but allow it to run freely from end to end of the stand.

This block, with the fork and lever attached, is shown separately at E. The fork and lever are hinged to the block at its top and can be moved from the vertical to a horizontal position. When about to be used the block is moved till the points of the fork are just beyond the backmost cord of the simple, the lever being in an upright position.

By means of the loops tied to the simple, as shown at figure 46, the required cords are drawn forward and the upper prong of the fork inserted in the opening thus made. Then, grasping the lever, the boy draws it down and holds it. The result of this is that the selected lingoes and leashes are drawn and held up.

At No. 2 three sections of the simple are shown lettered B, C, and D. At B the cords are at rest. At C some cords have been selected and the fork inserted. At D the lever has been pulled over and the cords drawn over with it.

Figure 47 shows the mechanical drawboy, a machine invented in the seventeenth century and improved during the eighteenth. It was attached to the pulley cords of the loom, on which, when the machine was used, the tie-up of the design was made, instead of on the simple. The active part of this machine is the pecker, which by means of two treadles and some little mechanical arrangements had two movements: (1) It rocked from side to side; (2) it moved, as it rocked, along the machine from one end to the other. Through holes in the side cross-pieces of the frame strong cords terminating in heavy weights were hung. To the tops of these cords the loops of each row of tie-ups were attached in regular succession. Only two rows are shown connected in the diagram to prevent confusion of lines.

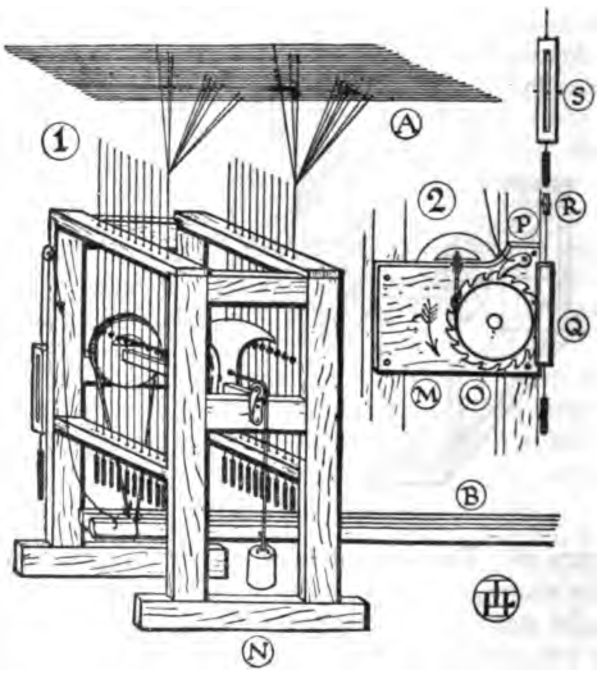

FIG. 47.—The mechanical drawboy.

The pecker had a deep notch cut in its points and was of such a size that as it rocked the cord toward which it inclined caught in the notch. At the center of the cord a large bead was fixed. When the rocking pecker came in contact with this bead it pushed it and its cord down and held it until the second treadle moved the pecker in the opposite direction.

As the pecker traveled along the shaft each cord was drawn down in its turn, thus opening the shed, line by line, for the working out of the pattern.

The number of lines in the length of a design, of course, had to correspond with the number of cords in the machine. The drawboy machine was not to any great extent used for the purpose for which it was intended, viz, to supersede the drawboy of the compound figure weaving loom. I suspect the boy was useful in many ways about the loom, and, moreover, his wages would be no great matter. But late in the eighteenth century, and well into the nineteenth, the machine received a good deal of attention and was improved and adapted for use with the treadle hand loom. It enabled the weaver to work any complicated system of heddles, for small-pattern fancy weaving, with only 2 treadles instead of 20 or more.

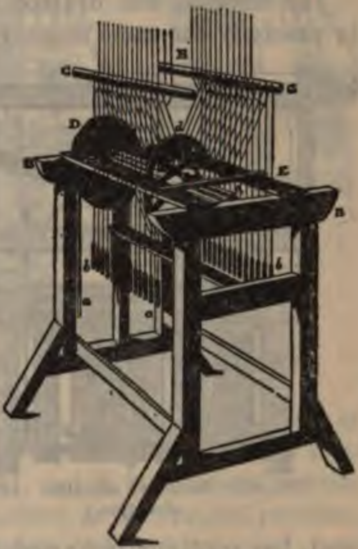

FIG. 48.—The mechanical drawboy. (Early nineteenth century.)

Figure 48 is from Porter's Treatise on Silk (1831). It represents an improved drawboy machine for which the Society of Arts awarded a prize in 1807. Further improvements were made later, but it was finally superseded by the famous machine which was perfected by Joseph Marie Jacquard, and known in England as the "Jackard" machine.

There can be no doubt that it is to Jacquard that the credit of rendering this machine thoroughly practical is due, although it has been proved that the fundamental idea of it, which consists in substituting for the weaver's tie-up a band of perforated paper was first applied to the draw loom in 1725, while in 1728 a chain of cards was substituted for the paper and a perforated cylinder also added.

These early contrivances were placed by the side of the loom and worked by an assistant. In 1745 Vaucanson placed the apparatus at the top of the loom and made the cylinder rotate automatically. But it was reserved for Jacquard to carry the machine to such perfection that, although many slight improvements have since been made in it, it remains to-day practically the same as he introduced it in 1801, notwithstanding the astonishing development of textile machinery during the nineteenth century and the universal adoption of the machine both for hand and power weaving.

Although the invention was introduced to the French public in 1801, it was not till 1820 that a few Jacquard machines were smuggled into England and secretly set up. In spite of much opposition they soon came into general use, first and particularly for hand looms and silk weaving, but afterwards for power looms, all kinds of fancy and ornamental webs being since their adoption woven by their means.

May I here repeat and emphasize that the invention of the Jacquard machine did not alter in the least the draw-loom method of pattern weaving? It only took the place of the drawboy and the pulley box, and substituted the endless band of perforated cards for the weaver's tie-up.

The designs, too, drafted on ruled paper, would be worked out in precisely the same manner, whether for tying up on the cords of a simple or for punching in a set of Jacquard cards. Each card, in fact, takes the place of one row of loops of the tie-up.

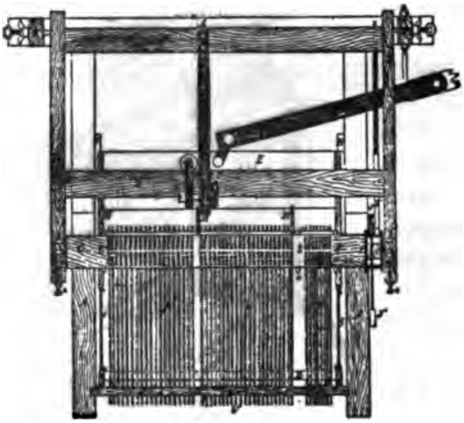

Fig. 49.—Jacquard machine. (Front elevation.)

The term Jacquard weaving, then, which one so often hears used, is a misnomer. It should be draw-loom weaving with a Jacquard machine, the machine being only an ingenious substitute for a less compact and manageable adjunct of the draw loom, an adjunct, moreover, which, as we have seen, has continually varied from the time of the invention of this form of loom. After the draw loom itself I should class the Jacquard machine as the most important invention in textile mechanism. It therefore claims a careful description.

Figure 49 is a drawing of the front elevation of a 400 Jacquard machine. The number 400 refers to the number of needles and hooks with which the machine is fitted up. These needles and hooks answer to the number of the simple cords of the draw loom. A design is still technically spoken of as being drafted for so many cords.

The position of the machine in the loom is at the top, where it is fixed on a solid frame just over the comber board, usually with its end to the front of the loom, so that the elevation shown in the figure is parallel with the side of the loom frame.

The machine frame is oblong in shape. It is made of hardwood for hand looms and of iron for power looms. But in either case it needs to be of great strength. To the principal frame a smaller one is hinged at the top, so that it can be raised like a flap.

In this drawing 50 wire hooks are seen standing upright on the bottom board of the machine. The bottom board is perforated with as many holes as there are hooks in the machine, in this case 400. The hooks represented are only one rank out of eight, which the machine contains. Each hole in the bottom board has a dent or groove cut across the top, in which the bent end of the wire hook rests. This keeps the hook firmly in position, especially when the necking cords of the harness are brought up through the holes and looped on to the wire.

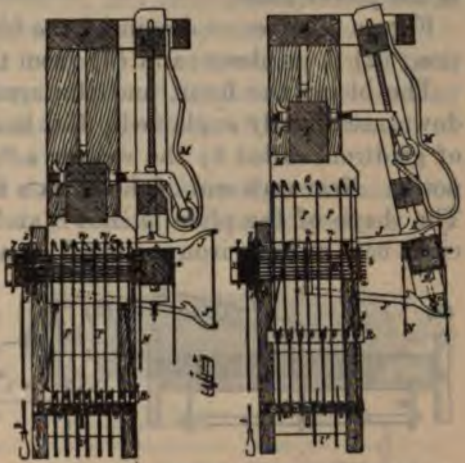

FIG. 50.—Sections of Jacquard machine.

Figure 50 gives two sections of the machine, one showing it at rest and the other showing it in action. In both sections 8 hooks are drawn, 1 from each rank of 50.

The hooks have the necking cords attached at the lower ends, and just below the small hook at the top may be seen a set of eight wires crossing them at right angles. Each of these wires, called needles, is bent into a loop or eye, where it crosses one of the hooks, and it is because the hook is passed through this eye that it is retained in an upright position. Figure 51 will show this arrangement quite clearly.

Each hook thus resting on the bottom board, and held down by the weight of the leashes of the harness, though supported at the top by the eye of the needle, through which it passes, is still free to rise and raise with it the leash or leashes to which it is attached.

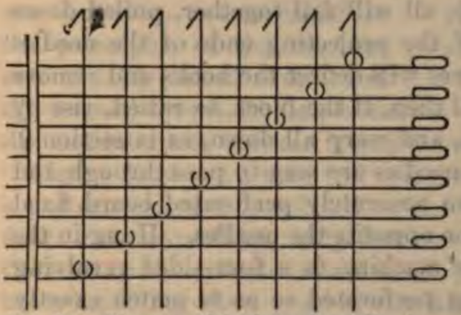

FIG. 51.—Diagram of hooks and needles in a Jacquard machine.

Leaving the hooks thus standing, let us consider the arrangement for lifting them.

Above the hooks the section of a solid block of heavy wood or iron is shown. This block runs from end to end of the machine, and has projections at its ends which fit into the narrow spaces between the two pairs of uprights of the machine frame in such a manner that the block can be caused to slide up and down steadily but freely.

Now, let us look at the block in the drawing of the front elevation (fig. 49) and then at a drawing showing the block in detail, separately.

The lever for raising the block, being extended to a convenient length, is connected by a rope to a treadle worked by the weaver's foot in the hand loom, or by any ordinary mechanical arrangement in the power loom.

Figure 52 gives us details of the block (1) as seen in front elevation; (2) from above; and (3) from the end.

The block, the lever, and the arrangements for sliding up and down are already explained. But hanging from the block is a kind of gridiron, called by the weaver a "griffe," which requires careful notice. Near each end of the block a flat plate of iron is firmly fixed. The shape of the plate is shown at No. 3, and between the plates, eight bars of hoop iron are fitted, as at No. 2. These bars are placed diagonally (see No. 3) and their top edges are sharpened so as to fit under the carefully made small hooks at the top ends of the upright wires as they stand in their several rows.

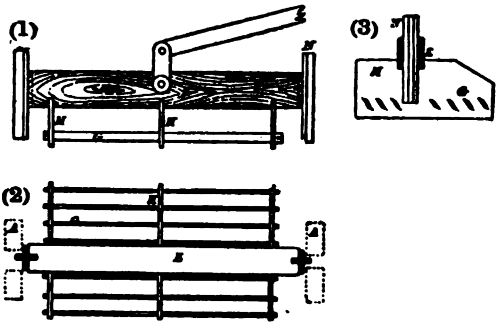

Fig. 52.—Details of the block of a Jacquard machine.

The first section of figure 50 shows the block at its lowest position, with the hooks caught on the bars of the griffe. Should the block now be raised the whole of the 400 hooks will be drawn up and the whole warp will rise with them. When released, of course, all will fall together, pulled down by the lead weights. Again, if the projecting ends of the needles are pushed inward, the needle eyes will deflect the hooks and remove them from the griffe, which will then, if the block be raised, rise by itself, leaving the hooks, leashes, and warp all down, as in section 2.

In section 2 the points of the needles are seen to pass through and project beyond the surface of an accurately perforated board fixed to the front of the machine frame opposite the needles. Hung in the frame, hinged to the top of the machine, is a four-sided revolving bar, or cylinder, each side being perforated so as to match exactly the perforations of the needle board.

If the flap, with the cylinder in it, be pressed against the board, and the block raised, nothing different will happen, because the points of the needles will have been free to enter the holes in the cylinder. If, however, a card covering all the holes be fixed to one side of the cylinder and the cylinder then be brought close up, presenting each side in regular succession, every time the card comes in contact with the needle points the needles will be pressed inward, push the hooks off the bars of the griffe, and the block will rise without them.

It follows, then, that if we interpose between the needle points and the side of the cylinder, as it presses the needle board, a card perforated according to an arranged design, wherever a hole is covered by the card a needle will be pressed in, and consequently a hook will be pushed off the griffe bar and left down as the block rises.

Each card, therefore, affects, in one way or another, every hook in the machine with its necking cords and leashes; and these, of course, determine the rising or remaining down of every thread of the warp from edge to edge of the web.

At the back of the machine a shallow box is fitted, containing 400 small spiral springs, one for each needle. When, therefore, any needle is pressed inward by the card on the cylinder, its opposite end is forced into the spring box, but as soon as the pressure is relaxed the needle, driven back by the spring, regains its normal position, holding the hook upright.

The mechanical contrivances by means of which the cylinder is moved, pressed against the needle board and rotated as the block rises and descends, are most ingenious, and subject to a great deal of variation. They are, however, not essential to the principles of the machine and can be passed over. But the method by which the perforated cards are adjusted to the cylinder and interpose between it and the needle board must be explained.

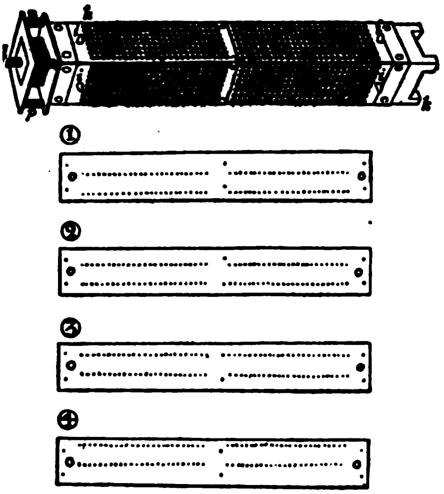

Fig. 53.—Jacquard cylinder and cards.

Figure 53 shows a detached cylinder and four cards punched with a pattern called a four-lined twill. This pattern repeats on every four lines; accordingly only four cards are needed to weave it. At the ends of the cylinder, close to the perforations, pegs are fixed and holes matching these pegs in size and position are punched in the cards. These pegs hold the card in its proper place, so that its perforations correspond exactly with those of the cylinder.

Each side of the cylinder as it rotates, being covered with a card held close to it by two elastic bands will press against a different set of needles at each of its four movements. The fifth movement, of course, brings the first set of needles again into play. When, however, as is generally the case, more than four lines of design are required, the cards have to be laced together in an endless band hung upon a rack at the side of the loom, and carried around the cylinder.

The most striking advantage of the use of the Jacquard machine in the textile arts is the facility it gives for a frequent change of design. It is only necessary to take down one set of cards and hang up another in order to change the pattern. The result of this facility was that the early part of the nineteenth century witnessed a perfect orgy of fantastic ornamentation. The manufacturers of all sorts of ornamental silk and fine woolen textiles vied with each other in the number and originality of the designs they could produce. The profession of designer may almost be said to be an outcome of the invention of Jacquard. Previously to this time the master weaver, or some person in practical touch with the looms, had arranged the design, and when once tied up on the loom it was good for a lifetime. But with the introduction of the new draw engine, as the machine was called, all this was altered, and restless change of pattern and fashion was the result.

At first the machine was only adopted in the silk trade for the weaving of rich brocades and other elaborate materials for dress or furniture, but ever since its introduction its use has been gradually extending, all kinds of plain and ornamental textiles being now made by its means, whether on hand or power looms.

As a work of mechanism it is truly wonderful. It can be made to govern all the operations of the loom except throwing the shuttle and actuating the lever by which it itself works. It opens the shed for the pattern, however complicated, regulates the length of the design, changes the shuttle boxes in proper succession, rings a bell when certain points in a design requiring special treatment are reached, regulates the take-up of the woven cloth on the front roller, and works out many other details, all by means of a few holes punched in a set of cards. Its great defects are the dreadful noise it makes, the ease with which it gets out of order, and the difficulty of putting it right. These render it only suitable for factory use, where noise does not seem to matter, and where a machinist is constantly at hand to keep the mechanism in good order.

So far I have traced the development of the hand loom, from its most primitive form to one of a high degree of perfection, as a tool for the skillful artificer. Here I must at present leave it and turn to a brief consideration of the machine loom actuated by steam or other power.

In order to find the earliest recorded attempt to weave by power we must carry our imagination back to the latter part of the sixteenth century and look in on the fathers of the city of Danzig in council chamber solemnly assembled. They are deciding the fate of a prisoner accused and found guilty of the crime of inventing a very

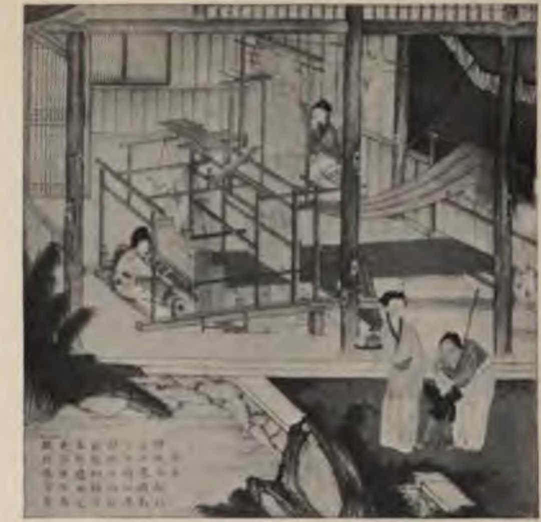

FIG. 44.—CHINESE DRAW LOOM.

(From an ancient drawing.)

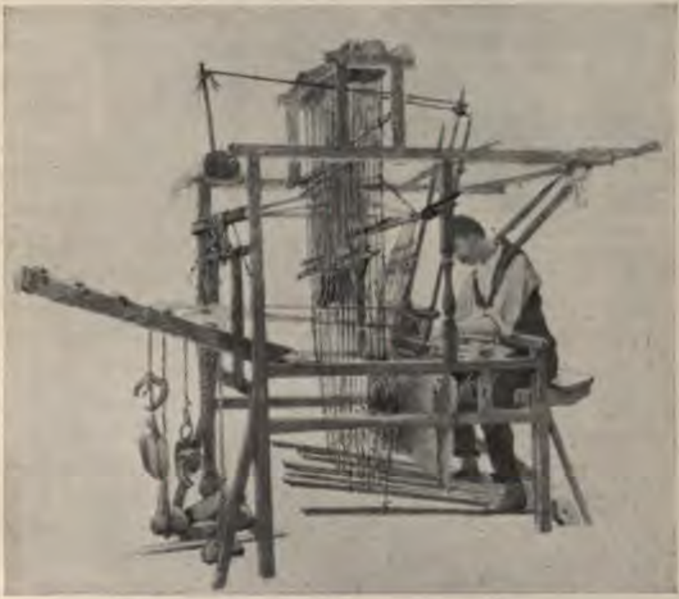

FIG. 54.—NARROW SILK WEAVER AT WORK.

(From a drawing by the author.)

ingenious machine for weaving narrow tape several breadths at a time.

The council, having carefully considered the machine, and bearing in mind the state of the trade, were "afraid that by this invention a great many workmen might be reduced to beggary." They, therefore, mercifully ordered the machine to be suppressed and the inventor of it to be privately strangled or drowned!

The weaving trade has always been divided into two great branches. The broad weavers made stuffs for garments and furniture seldom less than 21 inches wide. The narrow-branch weavers make ribbons, laces, tapes, braids, galloons, and such like goods, and of course when these were only woven in single widths on hand looms vast numbers of persons were employed in weaving them. There was a great demand for such goods in the middle ages.

Figure 54 (pl. 10) shows a narrow weaver at work on a hand loom. I discovered him the other day in a small trimming factory near Piccadilly Circus. The loom he is working at is an actual survival of the eighteenth century. There are several others in use at the same factory, where braids and trimmings for high-class furniture are always being made.

Attempts were made at various times in the seventeenth century to introduce the machine tape loom, but complaints and rioting prevented them succeeding. It was not until the eighteenth century that prohibitions were finally revoked, and the Dutch bar loom, as it was called, came into general use.

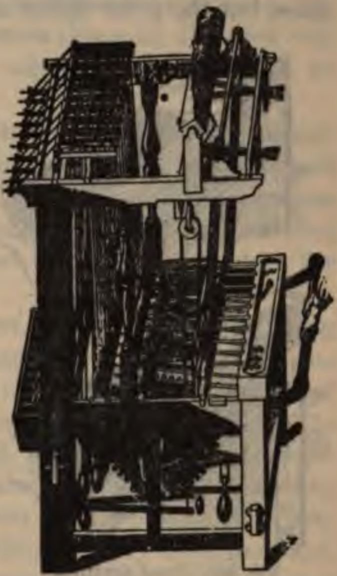

FIG. 55.—Dutch bar loom.

An illustration of this loom is given in the great French mechanical encyclopedia published in 1786. It is reproduced in figure 55.

The reason why the ribbon loom was so readily made workable by power was because it did not require the one movement which has always been the great obstacle in the way of weaving broad webs on machine looms—that is, the throw of the shuttle. Nay, not so much the throw, but the catch of the shuttle.

Figure 56 shows the graceful operation on which good weaving depends, an operation which has never yet been successfully imitated by machinery and probably never will be.

The operations of the loom in weaving are four in number: To open the shed, to throw and catch the shuttle, to beat the weft together, and to wind up the woven cloth. All these, except the second, are comparatively easy to arrange for, even in broad weaving, by means of a power-driven turning shaft furnished with cranks and eccentrics, fitted up in some convenient position in the loom. In narrow weaving the spaces of warp are so small that the passing through of the several shuttles presents no difficulty; consequently the invention of a practical automatic machine loom for narrow weaving was an early one.

Many attempts were made in the seventeenth and early part of the eighteenth century to weave broad webs by power, but they all failed to solve the problem of the shuttle. It has been partially overcome since, but the great defect of the machine loom to-day is in the driving and catching of the shuttle.

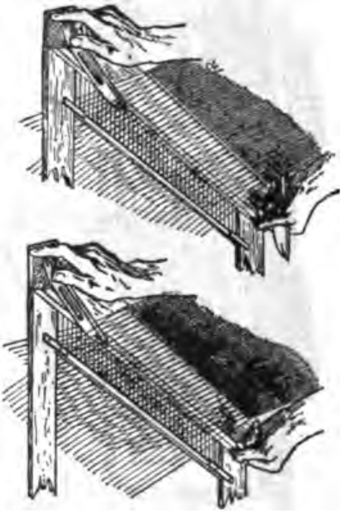
FIG. 56.—Hand shuttling.

The invention which partially solved the difficulty and eventually rendered the machine loom practicable was the fly shuttle, intended by John Kay, its inventor, for use on the hand loom. Its purpose was to enable the weaver to weave, without the aid of an assistant, wider webs than he could manipulate with the hand shuttle.

Figure 57 represents the batton used for the fly shuttle and should be compared with the hand shuttle (fig. 56).

The difference between hand shuttling and fly shuttling can almost be distinguished by comparing the two shuttles used. The hand shuttle is slightly curved and adapted nicely to the position of the weaver's fingers. The fly shuttle, on the contrary, is rigidly straight, so that it flies along in front of the reed, without any bias, from one end of the race to the other.

Comparing the battons, it is seen that the race block of the fly-shuttle batton is elongated at the ends. On these ends the shuttle can stand clear of the cloth which is being woven, and which is, of course, never wider than the reed.

These elongated ends have a bar of wood so fixed in the front that there is just room for the shuttle to run in and rest between it and the back of the shuttle box, as the elongated end is called.

Above the shuttle there is a thin, smooth iron bar, and on this the driver (enlarged at F), made of tough leather, is fitted so that it will easily slip from end to end of the box. Both boxes are furnished with drivers and are fitted up in exactly the same manner. The two drivers are connected by a thin, loose cord, having at its center a handle. The loose cord is suspended from the bar above it merely in order to keep it off the level of the web. To drive the shuttle across the race, the weaver grasps the stick, after placing the shuttle in the box near the driver, and, with a sudden jerk to the side he wishes to send the shuttle, pulls the driver along the bar with just sufficient force to drive the shuttle into the opposite box. By a slight turn of the wrist—which is difficult to acquire and impossible to imitate by a machine—the opposite driver is brought forward to meet the shuttle as it enters the box. If this be properly done there will not be the least rebound, and the weft will be laid evenly and straight. If, on the contrary, the shuttle be allowed to rebound, the shoot of weft will be loose, and when beaten down by the reed will show kinks and loops. Moreover, the edges of the web will be uneven.

Previously to this invention all attempts to pass the weft through the shed in machine looms failed to achieve anything like the speed of the hand-thrown shuttle; consequently they could not compete with the hand loom. Even when the fly-shuttle method was adopted the difficulty of catching the shuttle baffled the skill of inventors for many years.

The attempts of inventors to produce an automatic broad-weaving machine resulted in the construction of many weird though ingenious contrivances bearing more or less likeness to the hand loom in general use. Many of these were patented by their inventors, but failed to prove practically useful. It was not till 1786, when Dr. Edmund Cartwright devoted himself and his fortune to mechanical invention, that a practical broad-weaving power loom was evolved. Dr. Cartwright established a weaving and spinning factory at Doncaster, but after spending £30,000 and nine years in experiments he was obliged to give it up. He had, however, succeeded in devising a power loom for plain weaving, which it was believed could compete with the hand loom. Several of his looms were bought by a Manchester firm and set up in a factory. They are said to have performed their work well, but the factory was, shortly after its starting, burned down by an infuriated mob of hand-loom weavers.

Figure 58 is a photograph from one of Dr. Cartwright's designs for a power loom. A careful examination of it and its specifications shows that the doctor had many ideas which were long afterwards adopted by improvers of power-loom machinery.

Figure 59 is a drawing of a machine loom constructed by a Mr. Horrocks a little later than Dr. Cartwright's time. It is said to have become largely used. It more closely resembles the fly-shuttle hand loom than any of the other inventions. I should think it was only capable of weaving very faulty cloth.

By the end of the eighteenth century, it is said, there were 20,000 power looms at work in Great Britain against 250,000 hand looms. The power looms, like the hand looms, were constructed mostly of wood, and must have been clumsy and uncertain in their performances. Owing, too, to the greater strain of power weaving they must have quickly worn out.

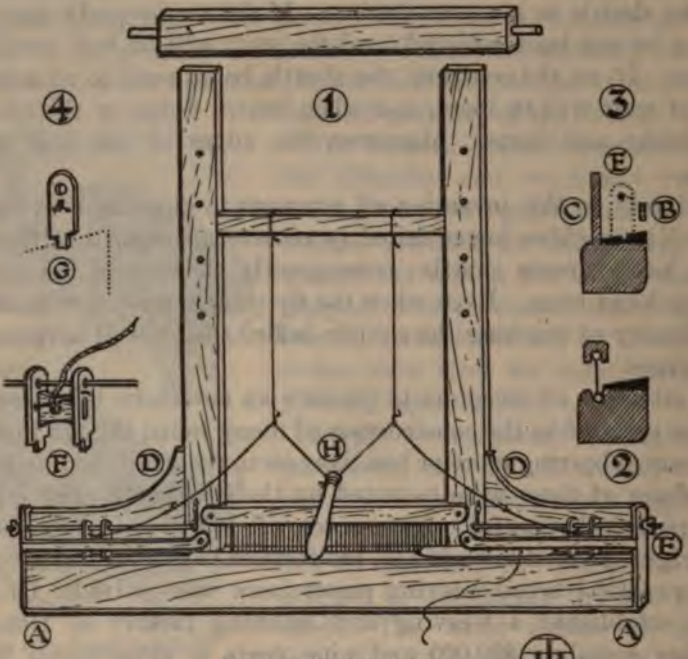

FIG. 57.—Fly-shuttle batton.

It was a long time before a convenient form for the power loom was generally adopted. Curiously enough, the form at length settled on was designed for a hand loom in 1771.

The inventor of this loom (fig. 60) was a Mr. Almond, who exhibited and worked it before the Society of Arts, and received a prize of £50 for his encouragement. Its chief feature is the inverted batton. It has also extra rollers, by means of which the length of the loom is greatly diminished.

A power loom erected for Mr. Monteith, a Glasgow manufacturer, about the beginning of the nineteenth century by a loom builder named Austin is extremely like Almond's hand loom.

Mr. Austin presented a model of this loom to the Society of Arts, of which figure 61 (pl. 11) is a representation.

Having settled on a general form suitable for the power loom, inventors next directed their attention to strengthening it and perfecting, as far as they could, its various parts. Take-up motions, contrivances for detecting broken threads, quickly stopping the loom, throwing the shuttle, etc., occupied their attention, and the loom became more and more accurate in its different performances as time went on.

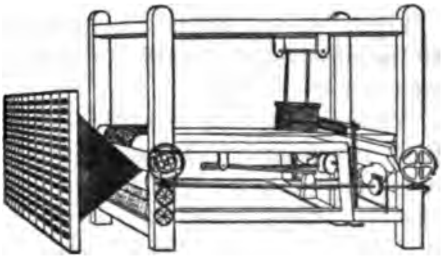
FIG. 58.—Dr. Cartwright's machine loom.

Iron took the place of wood all through the machine and the loom, actuated by steam power, has by now become, except in the matter of working the shuttle, a very perfect automatic machine.

Figure 62 (pl. 11) is a modern steam machine loom for weaving silk. You will notice at once how the levers for driving the shuttle, and the shuttle boxes, have increased in size and strength. It was found that in order to catch the shuttle and prevent it rebounding its entry into the opposite box had to be resisted. This rendered it necessary that the shuttle itself should be enormously increased in weight, and that great force should be used in driving it. Half the power expended in actuating the machine loom is required thus to drive the shuttle into the opposite opposing box.

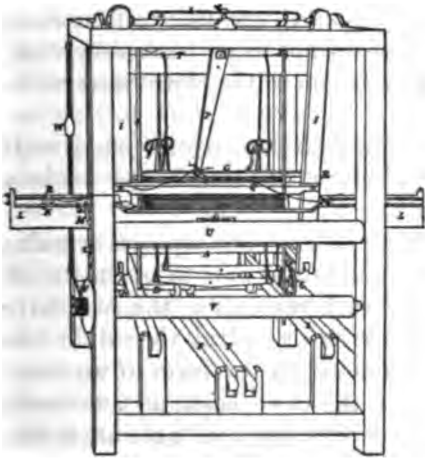
FIG. 59.—Horrocks's machine loom.

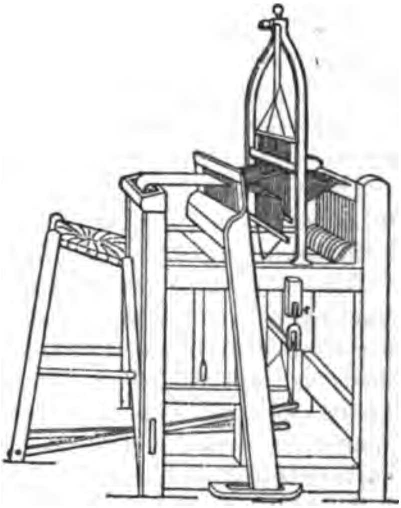
FIG. 60.—Almond's loom.

The addition and adaptation of the Jacquard machine to the power loom was not attempted till late in the nineteenth century, but when that was done the loom had arrived at the point of development at which we find it to-day.

A few months ago my attention was called to an illustration in the Manchester Guardian which represented a new weaving invention, and, on reading the description of it, I found that the inventor—Mr. Whalley, of Clitheroe—claimed to have solved the problem of the shuttle, which I have pointed out has been the chief obstacle in the way of weaving by power.

Figure 63 (pl. 11) is a photograph of the new loom, which appears to me to be likely to revolutionize the construction of machines for weaving by power.

Although at first sight this loom seems to be altogether different from previous inventions, an examination of it proves that in most essential points the tradition of weaving, which I have attempted to explain, still governs it. Three great advantages are claimed for it—(1) it is practically noiseless; (2) the weft has no jerk or strain upon it; (3) very little power is required to drive it. In addition to this, webs of between 11 and 12 feet wide are woven on it.

There is not time for me to give an adequate description of this important invention, but I must notice its salient points, and show (1) how it differs from the ordinary power loom and (2) how the traditional principles of weaving are still carried on in it.

First, as to points of difference: All the operations of the loom are worked out by its simply turning on its own accurately centered axis.

By an uninterrupted circular movement in one direction the warp is drawn off the warp beam, the shed is opened, and the weft inserted, the weft itself is gently pressed close instead of being beaten together, and the woven web is delivered and rolled on to the cloth beam without any strain or jerk whatever.

There is no shuttle. A case for the flexible cop of wound weft takes its place. The cop itself is of enormous length and holds a hitherto unheard-of quantity of yarn.

While the whole loom and its fittings revolve, the cop case remains stationary, balanced in the shed, and allows the weft to be drawn off it continuously in one direction, as, at each revolution, the successive sheds are opened. This forms, of course, a spiral thread in the woven cloth, the cloth itself being produced in the form of an enormous tube. As the cloth passes on to the cloth beam an automatic knife cuts it at a place where specially woven doup selvages are made.

So far all is new. The rest of the mechanism is an ingenious rearrangement of the traditional parts of a loom. The description of these essential parts requires a diagram of a section of the loom, which we have in figure 64.

In the center of the section is the steel axis, which runs the whole length of the loom.

The perforated comber board, instead of being straight and horizontal, as in the ordinary loom, is circular, and is duplicated, the holes being most accurately pierced.

The holes in these circular comber boards are very close together, and there are as many holes as there are threads of warp.

In each of these holes there is a long steel needle, with its eye in the center, the needle itself being rather more than twice as long as the space between the two comber boards.

These needles fit loosely into the holes of the comber boards, so that when they reach, as the loom revolves, a position above the horizontal center of the machine they rest against the central core of the loom.

But when in turn the needles come below the horizontal center they project through the holes of the outer perforated circle as shown in the drawing.

A thread from the warp beam is drawn through the eye of each needle, and, when passed through the circular reed and fastened to the cloth beam, will, of course, follow the movement of the needle as it falls against the core at the top or projects through the holes of the outer comber ring. This is shown at Nos. 3 and 4, which are longitudinal sections.

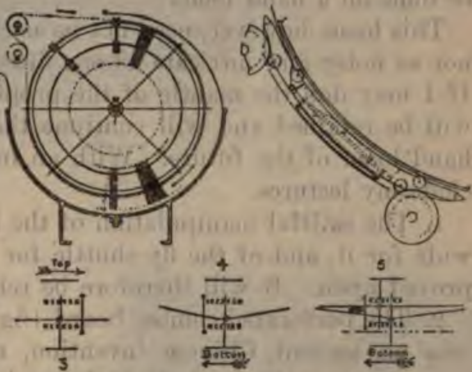

FIG. 64.—Section of Whalley's loom.

An endless band of cards, similar to those used for the Jacquard machine fits to the outer rim and governs the design. Where these cards have holes in them the needles fall through and draw down the warp thread entered in them, but where the card is plain the needle retains its position. This is shown at No. 5, where an open shed is represented.

No. 2 shows the cop of weft in its case in position for working, where it is retained by two smooth bowls of bosses fixed in their places on the stand or underframework of the loom. The opened shed surrounds the cop case, passes along it, and when it leaves it it, of course, incloses the weft.

By an arrangement at the top of the loom the reed is slightly pushed forward so that it gently presses the weft into its place as it passes a certain point. Very little pressure is sufficient, as only a few inches are affected at a time.

Time forbids me to attempt a description of other details of the circular loom, some of which, no doubt, will be altered and improved. But sufficient has, I hope, been described for the general idea of the machine to be understood, and its great achievement, the continuous wefting contrivance, to be appreciated. Although the hopes of the inventor of this cicular loom may not at once be realized, I shall be surprised if the principle on which it works does not eventually become universally adopted for power-weaving machines, especially for plain or small-patterned webs.

Weaving in vast quantities, and cheaply imitating in inferior materials rich damasks and brocades of important and elaborate design is, I hold, neither wise nor desirable. The use of machine looms for this kind of work is therefore to be deprecated. The tender manipulation required for weaving the varying textures of the finest webs made in the eighteenth century, and in China and the East generally, is only possible on a loom as sensitive as the perfected draw loom, and by a craftsman who, understanding every detail of the mechanism, is capable of controlling it. If such perfect work be required it must be done on a hand loom.

This loom, however, need not be as cumbrous as the old draw loom nor as noisy and intricate as one fitted with the Jacquard machine. If I may don the mantle of the prophet, I should say three things will be retained and will continue the tradition of the past in the hand loom of the future. With an indication of these I must conclude my lectures.

1. The skillful manipulation of the hand shuttle for work not too wide for it, and of the fly shuttle for broader webs, can not be improved upon. It will therefore be retained.

2. The perforated comber board (fig. 45) which, as I have showed, was an ancient Chinese invention, must be retained. Probably, however, some arrangement of metal needles, such as those of the circular loom just described, will be substituted for the string leashes with their mails and lingoes. But all the upper complications of strings and cords will be dispensed with.

3. The principle of working out the design by punching holes in a band of cards will be retained, although the Jacquard machine itself will, I imagine, be superseded by an electromagnet placed above the comber board. This magnet will attract the metal needles and raise the warp, some arrangement being made so that only those needles wanted for making the required shed will be raised.

Everything else may go, and new contrivances be introduced, but it is on some such hand loom as this that I can imagine the master weaver of the future being able, not only to produce webs as exquisite as those of the best weavers of the past, but to carry the art forward to a higher degree of perfection than it has ever yet attained.

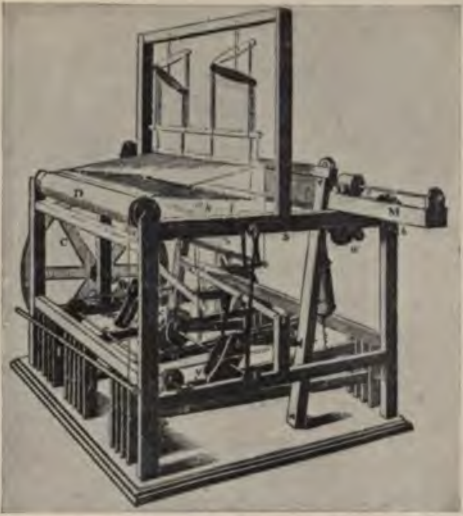

FIG. 61.—AUSTIN'S MACHINE LOOM.

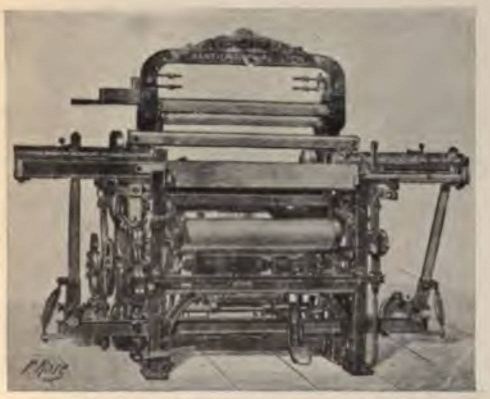

FIG. 62.—MODERN MACHINE LOOM FOR SILK WEAVING.

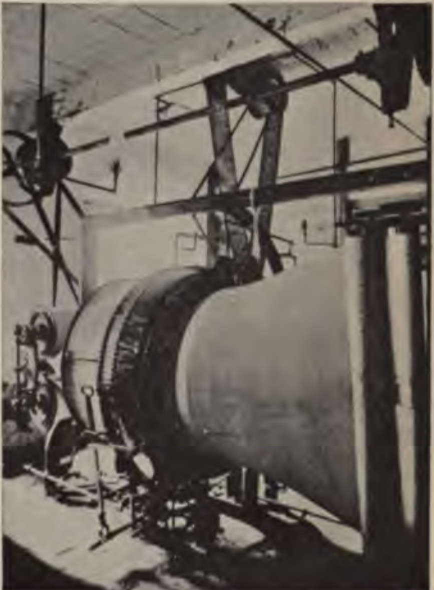

FIG. 63.—WHALLEY'S CIRCULAR MACHINE LOOM.

THE DEMONSTRATION PLAY SCHOOL OF 1913.[1]

By Clark W. Hetherington.

THEORY OF THE ORGANIZATION OF THE PLAY SCHOOL.

A.—THE IDEA SUMMARIZED, WITH COMMENTS.

The play school is a school organization with its program of activities and methods based on the central idea of uniting the spontaneous play life of the child who needs and desires leadership, with society's demand that he be instructed. It is an effort to solve the problems of elementary education by harmonizing the child's extra home educational experiences through combining in one institution the functions of the play center and the functions of the school; hence the term "play school."

Further, the plan correlates, through a simple administrable grouping of the child's natural activities and through an expansion of the idea of leadership, many of the apparently divergent ideals and methods in modern education which began with Rousseau, and, stimulated by recent profound social changes, have resulted in great educational restlessness and experimentation.

For the little children the plan absorbs naturally what is sound in the results of educational experience since Froebel's time and extends the process to the tender years of infancy. For the larger children it brings together in a practical school scheme and extends down the scale of years the valuable results and the ideals that initiated them in many recent educational efforts, namely, the outdoor school, the vacation school, gardening, manual training, organized excursions, camps, activities of the Boy Scouts and Campfire Girls, "training for citizenship," intensive individual development, etc.

The plan correlates and gives a balanced relationship between physical education, moral education, and cultural education. It lays the real foundation for vocational training and guidance. Above all, it establishes in school practice one of the more recent educational discoveries—the necessity of leadership in play from infancy to maturity and the educational superiority of leadership in play to instruction in work. It bridges the gap between play and work.

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[1] A report to Prof. Charles H. Rieber, dean of the summer session of the University of California, on the Demonstration Play School conducted during the summer session of 1913. The part of the report explaining the theory of the play school and describing its activities is an amplification of the brief outline submitted to Dean Rieber in the winter of 1912. The first draft of this report was submitted to several educators for criticism, and the author is especially indebted to Dr. E. C. Elliott, of the University of Wisconsin; President E. C. Stanford, of Clark College; Dr. C. E. Rugh, of the University of California; and Prof. M. V. O'Shea, University of Wisconsin.

Reprinted by permission from the University of California Publications, Education, vol. 5, No. 2, pp. 241–288, July 30, 1914. The second part, "The Summer Demonstration," pp. 279–288, is here omitted.

Therefore the play school may be defined as an outdoor school and play center combined; where the teacher's interest is centered in the children and their activities, not merely in subjects of study; where the educational efforts, including the moral and social, are put on a basis of practical living experience radiating into the whole environment; and where children are considered both as free active agents and as immature social creatures requiring aid, social control, and discipline. Instead of teaching subjects it organizes activities out of which subjects develop, as they have in racial history. The activities organized are the natural, more or less distinct, phases of the child's complete life. The usual school subjects develop as phases of these activities.

In spite of the inclusiveness of this ideal the play school plan as presented is not considered an invulnerable or perfected solution of the elementary school problem. No school scheme can be perfect so long as something is to be learned about child nature, or so long as society progresses, and no individual can present a perfect solution. That is a race problem. But the plan seems to meet in general the fundamental test of flexibility for progress with every advance in knowledge of child nature, education, or social need. Again, the plan is not presented in a spirit of antagonism toward the public school, but just the reverse. The widespread discontent with the public school is recognized, and my idea of the cause of this discontent is expressed. The plan proposes a step in organization and method that will make modern ideals and tendencies consistent and efficient in educational results and that will command the sympathy and support of the more progressive and intelligent parents and teachers. This sympathy and support are essential if the public school is to fulfill its functions.

The play school is not even presented as something entirely new. The scheme of organization and interpretation of activities are new, at least in form; and the extent of application of the idea of leadership and the degree of fusion of the functions of the child's play center and the school are new in emphasis. Yet the educational efficiency of the activities has been demonstrated in numerous schools, in modern playgrounds, and in boys' and girls' organizations. The whole idea has been approximated in many private efforts and in a few public schools. The convergence toward a fusion of the school and play center is seen, on the one hand, in the tendency of the school to organize the play life of the child, well illustrated at Gary, Ind., and, on the other hand, in the tendency of the best year-round playgrounds to organize activities that are usually considered school functions.

My own ideas [1] have been the product, first of reform-school work and then of intimate contact with the educational results of the lower schools through years of college teaching and experience in organizing play and recreation.

While the essential elements in the theory of the play school—namely, the identification of play with spontaneous living, and education with the process of living, both controlled by social conditions and depending in results on leadership—are as sound for the organization of secondary and higher education and even the molding of adult sentiments and customs as for the organization of the education of infants and children, yet this report is confined to the latter problem, because it is fundamental to the rest and because the problems of organizing activities and leadership are quite different after the capacity to work has been established.

B.—DIVISIONS OF THE REPORT.

An interpretation of the general theory of the play school, a description and explanation of its activities are given in divisions C and D, and conclusions concerning the demonstration of the summer of 1913 are given in part two of this report [here omitted].

C.—INFLUENCES DETERMINING THE ORGANIZATION OF THE ELEMENTARY SCHOOL.

The school as a social institution and the school process, typified by the curriculum, require a perpetual reinterpretation and reorganization corresponding to advancing knowledge of child nature on the one hand, and the demands of social progress on the other. Since the play school is a reinterpretation, it must be treated from both these standpoints.

1. Child Life and the Educational Process.

(a) THE CHILD'S SPONTANEITY AND PLAY.

A larger interpretation of the child's nature, especially in his play life, must be based on the fact that he is not merely a reflex mechanism responding to external stimuli, but a spontaneously active creature, driven by internal needs and hungers that are fundamental springs of conduct. Hungering for activity, experience, and expression, he develops his organic, nervous, emotional, and intellectual powers in the process of gaining adjustment.

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[1] I first formulated the play-school scheme as a school for subnormal children after two years' work in a juvenile reformatory, and presented it in 1899 while a fellow in Clark University to G. Stanley Hall. Dr. Hall urged at that time the organization of such a school in Boston, but it could not be financed. Later I used the term "play school" in my university extension of physical education and play in Missouri, especially in the campaign for the organization of playgrounds under the school boards of rural towns with the hope of fusing the functions of the play center with the school. I left the University of Missouri before any part of the larger idea was realized.

Spontaneously curious about his own activities and those of nature, animals, and man, he imitates them all until he masters their emotional and ideational content. He is spontaneously a manipulator of things, a juggler of impressions, and he constructs with things and ideas. He is spontaneously linguistic and "talks" until he can express what he observes, thinks, and feels. He is spontaneously social and enters into social relationships and organizations. He is spontaneously suggestible and educable; he is a follower, an imitator, a hero worshiper, craving leadership and instruction in ways of acting that will satisfy his hungers and give him adjustment.

This spontaneous expression of energy under the stimulus of hungers, controlled by instincts and modified by experience and social tradition and susceptible to leadership, is play. Play is not the popular "just play" nor the schoolman's "mere play." It is identical with the child's spontaneous living. Its relation to work will be considered later.

If time permitted, it would be possible to show that play began to evolve with the capacity to use experience and choose ways of acting, i. e., with the beginning of the evolution of intellect. It is just as deep in meaning as either the intellect or the will. Its function is to develop the latent plastic powers of rational man and keep him flexible through adult life. Play is the central element in the scheme of human nature that makes volition possible.

Infancy, biologically speaking, is a period for parental care during which time systems of nervous connections, feelings, and ideas are developed together through play in order that the nerve paths may be controlled in volitional or rational conduct.[1] Without play man is inconceivable; play makes volition and rational living possible. There is no meaning to the phrase "mere play," for play is the most important activity in life.

Play is nature's method of education. Why? Because education, in its broadest sense, is identical with the process of living. More specifically, it is learning how to live through experience. But experience comes only as the result of activity, and play is the fundamental form of all developmental activity. It is spontaneous living. Out of the various reactions upon the environment that we call experience comes the development of the instincts and emotions and the experience that makes for knowledge, character, and adjustment.

Schools, books, libraries, laboratories, and museums are only devices to give opportunities for activity. All these are worthless and the teacher is impotent without the activity of the individual to be educated; and play, as has been said, is the primary form of this activity.

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[1] These theoretical interpretations are drawn from a forthcoming volume on the Nature and Function of Play.

So striking is the child's expression of his energies, so broad his curiosity, and so intense his delight in his activities, that the most conspicuous thing about him is his struggle to gain an education; and his struggle is rational. He is as much "interested" in activities that develop his organic, nervous, and character powers as he is in getting information, and vice versa.

The child wants a real education; and he wants to get it in the only satisfactory way—just as the race got it, through experience. For years educators have been going to the child with their "priceless products of racial experience," and the child has said (by his reactions): "Go to; I don't want your canned goods. I want the fresh, juicy fruit of experience gained through my own activities"—and he gets it, though frequently it is of indifferent quality and often positively bad.

In his play, which is his real life, the child educates himself, even without instruction or aid. The result, however, depends always upon the character of the activities, and this is determined partly by the individual child's temperament, partly by his opportunities, and largely by the example and leadership supplied in his environment. Through these forces comes development, and character and ideals are formed. It is the duty of education as a social effort to feed the spontaneous life-hungers of the child with the wisdom of the race. Cooperation must be given that the play life may be broad, rich, and wholesome. Hence, individual leadership is essential.

Leadership means study, suggestion, direction. It may mean control in which discipline in work and duty have a place; it never means mere domination. This cooperation and leadership in the child's struggle for activity, experience, and self-expression, the play school proposes to give completely.

(b) RELATION OF PLAY AND WORK IN EDUCATION.

Disagreement concerning these principles may arise through old misinterpretations and confused notions about the relation between play and work. The fact that the child must learn to work can not be overemphasized, for he has needs, supplied during the early years by the home, that later he must satisfy through work. Moreover, if he is to become an efficient social being he must learn to perform duties that frequently are not pleasant and his adjustment will be flexible and complete in proportion as he masters the essential culture of the race. Born into a complex social order that is the product of long ages of social evolution, he must not only learn to work but acquire the capacity to work according to the conditions of modern society.

The ability to satisfy needs, to perform onerous duties and acquire culture demands the capacity for long-sustained volitio effort under the control of an idea of need or duty. This is work its developed form. This capacity to work is not achieved sudden It is an acquired trait. The infant has no capacity to work; t capacity is acquired, in the normally developed individual, duri the period between birth and maturity.[1] It appears in late infar and we exploit it in school by the sixth year. It develops ve gradually up to the age of 7, more rapidly from 7 to 12, and incre ingly fast during adolescence.

The rise of the capacity for work is associated with and direc dependent upon a correlated and parallel development of (1) t power for volitional action in the plastic nervous system through t developmental stimulus of activity in play; (2) the development the capacity for volitional attention through the exercise of refl attention in the instinctively controlled activities of play; (3) t development of the capacity for sustained enthusiastic effort throu the exercise of the emotion of expectancy which holds attention the emotion-suffused activities of play; and, finally, (4) the develo ment of a moral sense of purpose or responsibility or ambition, whi comes with a maturing of the social self.

The growth of all these nervous and mental powers that ma work possible begins in the simple and instinctive activities of t infant which every one recognizes as play. The young child can educated in no other way. But later the development may be co tinued either through play or work as above defined, and it is ju here that the confusion arises concerning the relationships of pl and work in education. To anticipate my conclusions, play, becau of its emotional accompaniment, is a more efficient developer of the fundamental powers used in work than work itself.

The child's activities develop progressively (1) in the muscu strength used; (2) in the variety, complexity, duration, and coor nation of movements; (3) in the number of instincts and desires a the form and intensity of their expression; (4) in the breadth of t associative processes used; and (5) in the span of sustained effort the accomplishing of a desired end.

Now, the activities exhibiting this progressive development m frequently be considered either play or work, according to the po of view. From the standpoint of the child there are only two clas of activity—internally impelled activity, or play, and externa impelled activity, or work. Any activity from the child's standpoi no matter what the powers used, the energy expended, or the duration of the effort, is play if it is internally impelled and satisfies the developing life hungers and instincts of the age period.

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[1] The roots of both play and work are present from the beginning. The struggle to satisfy phy needs or escape discomforts expressed by vocal, facial and general bodily movements may be called roots of work. The struggle to satisfy sense, nervous, and mental needs, or the spontaneous actions reactions of adjustment, may be called the roots of play. It is in these latter activities primarily tha the higher powers for work and play are developed.

From the standpoint of the adult, or objectively considered, the activities of the child that are sustained and have a purpose or future aim are apt to be called work; but, obviously, this is an interpretation of child life in adult terms. The adult, if he is an efficient social being, must work and he must recreate. No such situation exists normally in child life. The child gains his economic adjustment through the home. His play is both recreation and work and it is neither recreation or work; it is life. Before maturity his play activities are differentiated into the capacity for work and the need for recreation. The child's play is not recreation as usually understood and we can not insist on that too strenuously. Play is the child's chief business in life. In these internally impelled activities he lives and learns how to live. In them he should gain his primary development and life adjustment.

Play is as broad as the child's developing life. The activities frequently take forms that are not efficient from the adult or educational standpoint; but to identify the child's play with "fooling" or "futility" only, shows a twisted understanding of child nature that is a very subtle survival of medievalism in modern educational thought. This is exhibited in the shrinking from the idea of play as an educational force.

There need be no quibbling about the fact that a high capacity for work can be developed, has been developed generally in the past through work, though the efficiency of the majority of individuals developed by this method alone can be questioned. But the essential point to be recognized is that, all through childhood, play is superior to work as a developer of the nervous and mental powers used in work because of its emotional content. Moreover, the degree of development of the power for work depends upon the breadth and richness of the play experience.

Play is more intense, varied, and of greater duration because of the sustaining power of enthusiasm which postpones the onset of fatigue and reduces the consciousness of effort which characterizes the volitional attention of work. Therefore, as power is a product of activity, play is a better developer of nervous energy and volitional attention than work. It is essentially the developer of enthusiasm, which is the very essence of play.

Enthusiasm is expectancy: the emotional side of the instinct of attention, long drawn out or combined with the idea of an activity that will satisfy a hunger or developed desire. It is developed like any other capacity—through exercise in activities that feed the nervous and mental hungers and exercise the impulses characteristic of age periods. Enthusiasm is the spirit of healthy childhood. It carries the burden of sustained volitional effort until the capacity for sustained effort is established as a habit.

Play, therefore, is a better developer than work of the whole work mechanism. It develops organic vitality, nervous energy and skill, interests, volitional attention and enthusiasm together, as a unified and efficient working whole. Work is less effective because it disassociates the development of the capacity for enthusiasm from the development of the capacity for volitional effort and attention in realizing aims.

The capacity to work, therefore, as a part of the capacity to live, is best developed in the child's natural life or play. It is developed only in a negative way when the child sits still and does things foreign to its nature in obedience to the commands of adults. Such lack of activity depresses vitality and inhibits the development of the nervous system, volitional enthusiasm, and experience. It is one of the several factors that have caused children to "forget how to play."

The capacity to work from its simplest to its highest form is acquired most efficiently by living out in activity, broadly and intensely, the hungers and instincts characteristic of each age period; living them out in a social environment that supplies not only progressively greater opportunities for activity, experience, and self-expression, but progressively greater opportunities for accomplishment under a leader who molds ideals, and under social contacts charged with emulation. By realizing a progressive series of aims in play, the child learns how to work and to achieve life through work. This is the law of child progress.

If the capacity to work does not come out of these inspirations to live and work, nothing this side of a new ancestry can give it, and the individual is a subject for an institution for the socially dependent.

The developing work mechanism will be used in fulfilling social duties and obligations, when the social spirit in the child's instinctive loyalty, cooperation, self-subordination, and capacity for leadership is converted gradually into a consciousness of social relationships, interdependence, and obligations. This can be accomplished through the socializing influence of a progressive social experience under a leader who has in the background of his consciousness a social aim.

Again, the work mechanism will be used in acquiring racial culture and a higher adjustment through the use of books when social experience and leadership bring a consciousness of their worth. This will come early in some, later in others, probably not at all in many, but until books are attached to the central and developing enthusiasms in life, as aids in living, they will not be used extensively by the masses.

Vocational training and guidance are but a phase of this work-play program and not the first or most important one, since a vocation is but one form of adult adjustment, arising out of the child's progressive adjustment. A vocation is an individual matter realized through living, and in this living the individual should develop an enthusiasm for life and work; should discover, under leadership, his individual capacities and attach the enthusiasm and the capacity to that specialized social thing, an occupation.

Better educational results in general and a broader and higher capacity to work are secured by organizing the child's natural self-sustaining activities than by forcing upon him those foreign to his nature. To lay the foundation during childhood for efficient citizens and workers, the hunger for life, the power for sustained activity, the enthusiasm in doing and ideals in living must evolve together.

This natural method of developing workers will produce, has always produced, citizens to whom work is ''play'' because it carries the enthusiasm of play.

The difficulty in appreciating the law of learning how to work is the universal, thought-warping tendency of adults to interpret child-life in adult terms. The attitudes toward play and work need to be restated: (*a*) From an adult standpoint, play is a form of activity set over against the effort required by the driving necessities of adult needs; (*b*) from the child's standpoint, play is living; work is effort that has no connection with instinctive or emotional tendencies; (*c*) from an educational standpoint, play is a developer of all the fundamental powers of the plastic growing organism; work is an educational aim that is to be realized through living out interests characteristic of the several stages of child development until the work mechanism is established.

The law, then, of the relations of play and work in education may be stated as follows: Play, as internally impelled activity is practically the only method of education during infancy; is the most efficient method all through childhood; retains a conspicuous place during youth and even in adult life, as indicated by the modern attitude toward leisure time. Work, as externally impelled activity, has little place in the life of the infant, a subordinate though gradually developing place in the life of the child, but an increasingly important place during youth.

(c) PERFECTING NATURE THROUGH LEADERSHIP.

In many fields of human effort, notably in engineering and the production of domestic animals and plant forms, man has progressed by learning nature's laws and cooperating with nature or controlling

and perfecting her processes. In education, man has neglected, e
fought nature.

This is shown most conspicuously in the traditional attitude tow
play and the neglect of its physical, intellectual, and moral meani
Considered without traditional bias, education holds no antagoni
between play as the living out of hungers and instincts, and work
a developing capacity for efficient living in a highly complex, spec
ized civilization. Such antagonism is medieval and frequently c
ries with it a survival of asceticism. The traditional school evol
its organization for the convenience of the teacher in transmitt
information to a physically passive child. Play frequently in
fered with the teacher's program, hence was interpreted as a prod
of the imps. Does not this attitude still survive?

Because play has been despised, the programs for moral educat
are weak and bloodless. Morals and character in child life come
of living under influences that mold associated ideals and instinct
ways of acting; not out of drill in abstract precepts or in think
about conduct disassociated from real conduct, however valuable
latter may be when supplementary to the laboratory method, wh
is directed play. Ethical instruction, to be dynamic, must be bu
on a broad foundation of instincts trained in play, under a lea
who has the ethical aims and who will fix the ethical ideal. This
a practical program for the masses.

In the unnatural conflict between the mental and the physical t
bias in educational thought is even more apparent. The traditio
school has dealt with one narrow phase of child nature. It s
recognizes organic and nervous education with begrudging stingin
and is attempting to bolster the traditional program with a "sch
hygiene" that, as a substitute, is utterly futile. This superficial a
unscientific attitude is carried over from a phase of philosophi
speculation that has no place in education. Physical education
discussed as though it were a subject of study in the curriculu
instead of one attitude in considering the whole educational proc
of which it is the basic part. Physical education, as a special field
educational effort, arose because of the twist in educational thou
created by the rise of asceticism. It persists because of a survi
of asceticism. Because of this bias, the programs for physical edu
tion in most schools are pathetically superficial and the children sh
it. Vigorous, big muscle play is nature's method of physical edu
tion and bulks large in the efficient program.

So obsessed is our consciousness with the idea that education
something which comes from books, and so dominant has been
intellectual or cultural idea, that the masses of children are preven
from getting an educational experience. We insist that they sh
master the tools of learning before they get any experience, and th

that they shall take it secondhand. At one extreme there develops a group of individuals having the capacity to acquire large masses of book learning with a small foundation in practical experience; and at the other, a group who may or may not have had real experience, but who have a contempt for books and no realization of their value as essential aids in living or as sources of inspiration for a higher adjustment.

Modern literature on teaching is strewn with the word "motivation." Every effort to find a motive for an activity or a subject of study is a search for its basis in a hunger or instinct which underlies the child's spontaneous life. This search represents generally the attitude of the adult, with an adult's interest, trying to find some way of attaching that interest to the child's native tendencies. It illustrates the breadth of the psychic gap between the teacher and the child and the dominance of the attitude of teaching rather than leading.

Why not shift the problem from the organization of "subjects of study" that are selected products of racial achievement, to the organization of the child's own spontaneous active life; from the attitude of teaching primarily to that of leading (which includes teaching)? Why not abandon our indifference toward the child's play and recognize it as complete living, from his viewpoint, as well as the dominant source of all educational values? Why not put our aims and our specialized adult interests in the background of our consciousness and enter into the child's life from his point of view, meeting his hunger for life and his desire for leadership with the resources of the adult? In this way we can make his activities a source of inspiration to him and perfect their results from an educational standpoint. Does not this attitude complete modern tendencies in educational thought? Will it not make public education efficient for the masses?

In this larger conception of education, leadership is the prime essential. Teaching is but a part of the leadership for which the child's hunger is as conspicuous as his hunger for education. He craves life intensely, but his imagination outruns his skill and judgment. His resources are limited; his attention is fleeting; his enthusiasm breaks down. He must have leadership if his activities are to be satisfying or educationally efficient. Though he rebels at domination, he constantly appeals for help in finding something to do and in achieving his desires; and when leadership is given and accepted, he will submit to endless direction, and, as age advances, to increasingly severe discipline. This is proven daily on the play field and in boys' and girls' clubs.

By entering into the child's life, it is a simple matter to lead him so as to loop the cultural material of the race to his hungers and thus achieve results not possible under the subject-of-study teachi program. That process is inverted. It must be recognized, howev that there are enormous variations in children's capacities for progr in various activities and in their susceptibility to suggestion.

Here appears a danger. A vast difference exists between learni nature's laws in the development of child life and cooperating wi her or perfecting her processes through the child's susceptibility leadership, and the skillful exploitation of that susceptibility satisfy the vanity of parents or teachers whose minds are catalep under the obsession of some educational fetish. We are in so danger of entering into an age of child prodigies.

Objections are raised that education is inefficient because it made too easy. Signs of a reaction have appeared. Now, whatev of justice there may be in criticisms of "teaching through play," justice exists in criticisms of the leadership of play. This leadersh has its biological roots in the evolution of the interrelationshi between parent and child, and play is not "easy" in the sense of bei devoid of effort or hardship. Both the intensity and the durati of extreme effort in many forms of play activities are so striking th few adult activities can be compared with them.

Play is interesting, but to interpret education as something un teresting strikes the very nervous system of education with a pals and to say that because anything is interesting it is educationa undesirable is surely a survival of asceticism. We have failed education because we have ignored play and divorced educati from life.

The dominance in education of the play motive, or real living obedience to real present needs during child life, does not mean th there shall be no discipline. Living is discipline. The child, li his ancestors from the beginning, is driven by hungers and controll by instincts that are nonspecific. His conduct is largely the produ of experimental experience, which frequently causes pain as well pleasure. So was the conduct of his ancestors. As a result of rac experimentation, the child is born into a complex network of wa of acting, both good and bad. Lacking judgment and perspecti he is apt to imitate the bad examples in his social environment well as the good, thus forming habits, ideals, and character that bad for him and for society. To mold the ideals developing in t child's experience is the function of the parent and society's rep sentative of the parent, the leader, or teacher. Discipline by adul like leadership, has its roots in the biological relationships of pare and child.

Practically all the bad habits known to childhood and youth the product of our neglect of this function of leadership. Vi develop in play. This is the negative argument for putting mo education on a laboratory basis of directed play. The danger here is that, with the prevalent notion about "teaching," the tendency will be to control the experimentations too strictly and to control ideals before there has been experience.

To summarize, it would seem, therefore, that education will be efficient when we bring the resources of adults to aid the child in his struggle for activity, experience, and self-expression, and when adult leaders meet the child's hunger for guidance with the spirit of a superior playfellow and with the discipline of leadership. This the play school proposes to do.

2. Social Progress and the School Organization.

(a) INDUSTRIALISM, THE HOME, AND THE PLAY AND SCHOOL CENTER.

While the play school is primarily a product of child study, it is also demanded by the new educational conditions attendant upon social progress. No phenomenon of our civilization is more striking than the rise of modern industrialism, no force more potent in its influence on the home and child life.

In the past the home was the center of life and experience. The majority of homes were not only the centers of family life, but they were industrial and social centers, furnishing large opportunity for the child to see and participate in all the essential human activities. The factory took from the home both the industrial occupation and the machinery of manufacture, with all their stimulus and opportunity for child activity. Hence, the function and the size of the home have contracted, and with the contraction the function of the home as a social center has declined. Entertainments are sought outside in commercial amusement centers, with a further contraction of educational stimulus in the home. Moreover, the size of the family has decreased, leaving children not only without generous opportunities for activity, but without even the stimulus of an adequate character-building companionship. In a word, modern industrialism has squeezed the educational juice out of the home.

And, if we are to believe social workers, the squeezing process will continue. Criticism that places on parents the blame for their failure to supply educational needs which the home supplied a generation ago, misses the mark. Speaking broadly, parents are helpless. Even the most earnest frequently find themselves at their wits' end in trying to meet the life needs of their children. The masses have neither training for the problem, educational resources in the home, nor the financial ability to meet the need at home or in private enterprises.

With the continued domination of industry over our social life, the home will probably be less and less able to fill the educational needs of the child, and a greater gap between parental life and child life will develop. Adults must be specialists in order to be efficient, and they must struggle for leisure in order to have any degree of completeness in life. Both these conditions and the habits of adult life flowing out of them are foreign to child nature and life. So, if the influence of industrialism continues, the gap between the child and adult is bound to widen. Like all differentiations in the organic world, the greater the unlikeness the greater will be the interdependence. The child is dependent upon adult resources and organizing skill in order that he may have life; and the adult, who is to be the product of this child life, is dependent upon the child's living his complete life. The failure to supply that complete life gives us adults who are mere cogs in the wheel of a complex machine. This is the social educational situation even now.

Instead of the home and its immediate environment supplying practically all the opportunities for the child's activities, experiences, and expression, these functions are now divided among three institutions—the home, the school, and the play-center.

The home is still the center of domestic life, though even in the best homes it is greatly narrowed in its educational possibilities. Many homes are merely places in which to sleep and eat. Though they still have great educational influence, their educational resources are practically nil.

The school has absorbed an increasing amount of the child's time, but it has not, except in a few cases and in a limited way, even attempted to supply what has been eliminated from child life by modern social changes. As a prominent educator puts it: a generation ago, a boy had three months' schooling and nine months in which to get an education; now he has nine months schooling and three months in which to gain an education. Actually, the situation is even worse; since during the three months he has few opportunities for activities that educate.

The public playground is coming to fill the need for educational activity and experience otherwise limited by a physical environment that is unnatural, and a social one that is complex and specialized. At present most playgrounds are inefficient, because of public ignorance as to their functions and the prevalence of poorly trained directors.

The public playground is a child's community social center, and it should supply and does now supply, under expert play directors, not only the space, equipment, and companionship which are beyond the economic and social resources of the home, but the adult leadership that is essential.

Experience has shown that leadership is the first essential of a successful playground, for three groups of reasons:

(1) The playground is a democratic institution open to all children; hence, unless directed, apt to be dominated by the bully or the tough gang. It concentrates the bad manners, antagonisms, and vices of children; hence it is apt to be a breeding place for evil unless in charge of a director who is trained to convert these very tendencies into sources of moral discipline.

(2) The playground brings together a large miscellaneous group of children of different ages, temperaments, social training, and habits of play. This makes the play organization complex and beyond the democratic organizing power or self-control of children. The play breaks down without the superior skill and control of the adult leader who may, by bridging the difficulties of organization, make the playground the most efficient agency in existence for training in democratic citizenship.

(3) The playground is an institutional center for child life; a substitute for certain educational functions of the home, which the home can no longer perform adequately. The supervision formerly supplied by the parents in activities in which they were experts can no longer be supplied in the new activities. Few parents can be experts in child nature or the technique of a vast variety of activities that satisfy the progressive educational needs of children. This function must be taken over in its large and difficult phases by the professional trained leader. His influence should radiate from his center of business into the surrounding community, the home, and the school. Since the playground is a laboratory of conduct and its activities are the foundation for a modern democratic system of moral education, the director becomes the main influence for efficiency in this highest phase of education.

As the home approaches the apartment type and the family the one-child type, under the pressure of modern social conditions, the relative importance of the play center and school increases.

In this social situation child welfare requires a new spirit and a new organization of the school and playground. Both are extra-home institutional centers of child life and both exhibit the inefficiency of an incomplete organization.

As the playground is a center of life and education organized from the child's standpoint, and the school is a center of child experience and education organized from society's standpoint, the two institutions should be combined to unite the two points of view, and unify the child's educational experience. It is not sufficient that a playground space be added to the school or that a group of manual or other activities be added to the games of the playground. The play center and the school center must become one in spirit, aim, and organization.

A triangular division of child life under three classes of institutio
and the dual organization of extra-home activities are inefficient, n
only educationally, but administratively. Experience has shown th
children in cities will not or can not go more than one-quarter or o
half of a mile to a play center. Therefore, the provision of adequa
playgrounds within reach of every city child, and the organizati
of a staff of leaders, under some municipal administrative body apa
from the board of education, puts a double burden upon the ta
payers.

So far as the small town and country are concerned, few would su
gest, after the recent campaign for a wider use of the school pla
that a play center should be located anywhere except at the scho
still, where they have been so located, the functions of the play cent
and the functions of the school have not been identified.

The public school is the institution concerned with the educati
of the child; it must provide all his extra-home educational activit
if its functions are to be efficiently realized. As indicated before, th
is a different problem from the recreation of the adult.

(b) NEW EDUCATIONAL MOVEMENTS AND THE PLAY-SCHOOL IDEA.

Social progress has changed not only the relationships between t
home and the play center and the school, but it has brought a n
social conscience concerning education. We are in a period of ed
cational discontent, restlessness, and experimentation—a part
the general social discontent. Every man who thinks and who
sensitive to the spirit of the time reacts upon the educational situ
tion and usually has some "new" idea or variation of the educatio
program. Several new types of school and a generous number
new educational efforts, both without and within the public-sch
system, have been organized and promoted sufficiently to attr
public notice.

Of the new types of school one or two are significant. First th
is the vacation school, which is successful from the standpoint
child welfare and child interest. But it is simply a recognition
the fact that the child's education is going on 365 days in the year a
that the school must replace the home and community in supplyi
opportunity for experience.

Then there are the open-air schools, which have proved that
"model" ventilating schemes are delusions and that the most ratio
way to ventilate a school is to do away with most of the school wa
Now we are about to see the time-worn school idea run its vicio
circle again. "Adequate provision" is to be made for children ne
ing the fresh-air school. So (according to the program) masses
children will be kept indoors to be devitalized and subjected t
string of diseases with their train of adult weaknesses, while

tubercular and the anemic will have the privilege (until they get well) of the only type of school any child ought to have.

Ayers says that the open-air school will take its place in the history of education as marking one long step toward that school system of the future in which the child will not have to be either feeble-minded or delinquent or truant or tubercular in order to enjoy the best and fullest sorts of educational opportunity. Even in the colder sections of the country and during the severest winters, children can be made comfortable in the open air most of the day and for most of their activities. Until this common-sense standard is realized, school hygiene will progress with one leg paralyzed.

Significant for the future of the open-air school is the widespread rebellion among parents against putting their children in the public schools because they "will be shut indoors" or because they are "never well." Naturally, a large number of private outdoor schools are catering to this sentiment. Closely associated is the organization of country day schools, such as exist in Buffalo and Minneapolis, indicating that well-to-do parents are willing to pay high rates of tuition to have their boys go to the country each day.

Several new movements are strikingly significant of the trend in educational organization. Most of these are focused on the adolescent, yet the principles involved and their solution extend into the preadolescent period. Conspicuous among these movements is that of the Boy Scouts, with its highly elaborated program of activities and honors for achievements. This organization and that of the Campfire Girls are phases of the great movement for directed play and leisure time. They have arisen and attracted public attention because of the widespread feeling that masses of children are growing up incapable, resourceless, and irresponsible. Hence the new devotion to a program for achievement as a means of character development.

The Junior Republic, boys' cities, civic activities and responsibilities for boys, all indicate the rising social consciousness that children have their own sense of values and responsibility. This sense is just beginning to be organized for educational purposes. Increasingly as the years progress, the imagination is stirred by the relationship between approaching adulthood and the adult's activities. Since the results depend upon leadership, we have a host of social problems rising out of our past neglect.

Some of the "new schools," however, in which "real work" is the central idea of the program, have failed to achieve their ideals because the programs are based on ignorance of child nature or on the old notions of play or "work" that is a mere imitation of specialized adult occupations. Where these efforts have succeeded, especially for the younger children, leaders have organized "play" instead of "work" without knowing it.

The gardening movement, geography excursions, and the shift in nature study from that of plucked and dissected symbols to a study of nature in action—changing, growing, eating, reproducing, struggling nature with all its vital human relationships—all these activities emphasize the fact that "learning" must be a part of life and built on vitalizing, mind-filling experience.

The focal point of thought in these movements drifts toward the organization of the child's whole life experience on a concrete laboratory basis. It involves a recognition of child capacities and needs previously furnished in natural contacts with a simple adult life now passed away.

Vocational training and guidance are receiving their emphasis. Adjustment for the masses is the aim, but vocational adjustment is only one phase of life—the adjustment of the adult. Avocational or recreational adjustment, social adjustment, citizenship adjustment, and domestic adjustment are coordinate, and they all depend upon the developmental or educational adjustment during the years of growth. Obviously shallow is a vocational training and guidance that is not based on educational provisions that allow the child all his early years for enthusiastic living and achieving until the work mechanism is established and talents, interests, or capacities are developed, and until expert leaders who are guiding this living process may discover individual tendencies and adaptabilities. Furthermore, a vocational training that is not based on organic, nervous, intellectual, and moral development, and that is not coordinated with a social and recreative adjustment and a preparation for citizenship and domestic life adjustment, is bound to produce workers that are but inflexible cogs in the wheel of a gigantic machine which will inhibit both individual and social progress.

The new efforts for backward and exceptional children reveal the recognition of the fact that our wonderful school mechanism has failed in results for great masses of children. The consciousness is growing that the universal "child" when differentiated into individuals is as variable as the number of children and that each must be educated in a variable and adaptable program. This is perfectly practical when activities rather than subjects of study are organized.

The campaign for school hygiene has become almost hysterical. Accumulating evidence has shown the physical, mental, and moral effects of long hours, confinement and overpressure in mental work. Nevertheless, there is a demand for a broader manual training, a larger nature study, a fuller "physical education," and an efficient moral education—all interpreted as "subjects of study" and added to the old subjects, together with new phases of the arts, sciences, and literature pushed by a variety of individuals from the viewpoint of their own adult specialized interests.

Consequently, school hygiene will come out of the same door wherein it entered, so far as its larger functions are concerned, unless child life is put squarely on its two hygienic legs in school organization—the one an open-air life, and the other a program of activities instead of subjects of study.

Our educational fetish, the three R's, blocks the way. Certainly children must acquire the tools of a cultural adjustment; but is the learning to read and write and count at an early age more sacred than the health of our children and an enthusiasm in life that gives capacity to live and work efficiently? At present the danger is that the fetish will be imposed at 5 or even 4 years of age and some few children are able to learn to read and write during these tender years for the edification of ambitious teachers and vain parents. The point is not what some children can do, nor that they should not learn these essentials of a cultural adjustment during childhood. It is that to make reading and writing a requirement to which all other activities are subordinated, say up to the child's ninth year, is insupportable from a broad educational standpoint.

The time has come when men are beginning to realize that the stifling of the child's developing enthusiasms in life through a back-warping, chest-cramping, nerve-breaking, mind-deadening desk and schoolroom program of "studies" is as cruel as the Spanish Inquisition.

The tendencies noted point to the solution. All the vital special desires in education can be met, the overcrowding eliminated, the program increased to 8, 10, or 12 hours a day and through 365 days in the year, the present injury to health replaced by a positive construction of vital and nervous powers of which health is an index, moral education placed squarely on a laboratory basis, with each child treated as an individual as well as a creature to be socialized, and the "learning" increased both in quantity and quality by reinterpreting the school as an open-air, educationally fused play and school center, and by shifting the emphasis in the school program from subjects of study to the organization of activities which evolve with the aid of leadership into specialized, adult interests.

This solution, as indicated by the effect of recent social changes on educational practice, is also demanded by the social changes to come. Society has reached the age of human engineering, with child education as its foundation. The knowledge and skill are at hand. In the past, man's human engineering efforts were confined to correction and cure; medicine was the dominant human engineering science. In recent years we have learned how to prevent many individual and social ills. The sciences of prevention are now dominant and "hygiene" is in the air. But a new thought is already here—constructive effort. Social correction and medicine are still advancing, prevention is commanding public opinion, but both are more or less futile without a foundation of constructive engineering. And education is the core of all constructive engineering which deals with the individual.

Education is now the dominant science, the source of appeal in all social effort as well as in the efficient adjustment of the individual. Of the three forces determining what any individual shall be at maturity—heredity, activity, and environment—with the three corresponding sciences—eugenics, education, and social economy—activity alone is the source of power in the individual after birth. The environment sets conditions for activity, therefore influences its result; but activity itself is the developer of all power, and education the science of constructive effort with the individual. Old, neglected, despised education has become the new inspiration in human engineering.

Even the universities feel the new responsibility and schools of education are arising, still dominated by the old narrow ideas of education as an intellectual process, but destined to fulfill their real function, producing engineers of child life and child adjustment to meet the requirements of an advancing civilization. This is the hope for democracy and civilization.

3. The Play School a Reinterpreted School.

The play school is proposed as the next step in the evolution of the elementary school. (1) It is suggested as the extra-home institutional center of child life in which the school and the playground are educationally fused and their aims identified; and where the child's whole daily active life not supervised by the parents shall be spent through the entire year from early infancy until the capacity to work consciously for adjustment has been established. (2) It is proposed as a center in which children shall learn to live and to work with enthusiasm by living completely in their activities, which include the whole physical and social environment and are organized to satisfy fully the child's hungers for experience and self-expression. (3) It is proposed as a center for complete leadership, where the interest is centered in the child, not in subjects of study.

The aims of the play school may be summarized as follows:

(1) To organize the opportunity for a complete play life in order that the child may develop his powers, learn the meaning of his environment, and discover himself.

(2) To furnish leadership for the fundamental activities in order that organic, nervous, and volitional powers for activity with enthusiasm, and the capacity for work may be established.

(3) To connect the play tendencies and interests with materials for activity that will feed and develop stable interests and then connect these interests with the resources of society, especially literature.

(4) To secure close observation, clear thinking, skilled execution, and free linguistic expression in connection with all activities.

(5) To mold the instinctive and emotional reactions in all activities in order that sound moral habits, moral judgment, and social ideals may be established and come to control all developing powers for complete adult adjustment.

D.—THE PROBLEM AND ANALYSIS OF ACTIVITIES.

The proposal to organize activities instead of subjects of study shifts the practical problem in education to the study of activities and the educational leadership of these activities.

Educators have been devoted to the investigation of methods of teaching special subjects of study. They have spent relatively little time in studying the nature or the function of the child's spontaneous life activities and the relation of these activities to his development—organic, nervous, intellectual, and moral—or to his adjustment. Leadership in the organization of activities requires a knowledge and skill that makes the organized activities as natural as the unorganized, but more certain of educational results.

The child's activities may be studied from many standpoints, of which the following are examples:

(1) From the standpoint of the motor-mechanism used—
  The locomotor, or big-muscle mechanism;
  The manual, or small-muscle mechanism;
  The vocal and linguistic mechanism;
  The sense-attention mechanism, etc.
(2) From the standpoint of the regulating process involved—
  The instinctive and emotional processes;
  The intellectual processes.
(3) From the standpoint of the initial sources of the activities—
  (*a*) The hungers; organic hungers and needs for food, and the psycho-motor hungers for activity, experience, and expression, or
  (*b*) The stimuli of sense situations.
(4) From the standpoint of the genesis of the form of activities with interests, motives, beliefs, habits—
  The hungers;
  The instincts;
  Experience as a result of reactions upon environmental situations;
  Imitation;
  Conscious judgment.

- (5) From the standpoint of the educational results or values of the activities—
  - (a) For the development of the organism—
    - Organic development with a system of habits;
    - Nervous development with a system of habits;
    - Instinctive and emotional development with a system of habits;
    - Intellectual development with a system of habits and ideas, and
  - (b) For the adjustment of the organism to phases of racial activity and culture—
    - Economic, or vocational adjustment;
    - Recreative, or avocational adjustment;
    - Fellowship adjustment;
    - Citizenship adjustment;
    - Domestic adjustment.
- (6) From the standpoint of a practical educational leadership of the activities for complete child living.

All these points of view are important in the investigation of activity and in the training of the leader or teacher, but for the practical problems of educational leadership the last point of view is essential and may include all others. It is distinctly the leader's or teacher's viewpoint. It demands a classification of the child's activities that gives the more or less distinct, but natural, phases of his complete active life; and that makes it possible to administer his complete living. This classification is essential further as a basis for the organization of a progressive educational "curriculum" of activities: First, that will use all the mechanisms and regulating processes; second, that will feed all the hungers, provide for reactions upon the whole environment and give opportunity for full expression of all valuable budding interests; third, that will hold true all through childhood, tending to evolve naturally into the racial forms of activity; and, fourth, that will give all the educational values.

All those demands seem to be realized tentatively in the following classification: (*a*) Big-muscle activities; (*b*) manipulating and manual activities; (*c*) environmental and nature activities; (*d*) dramatic activities; (*e*) rhythmic and musical activities; (*f*) social activities; (*g*) vocal and linguistic activities; and (*h*) economic activities.

DESCRIPTION OF THE ACTIVITIES.

A description of each of these groups of activities will make its educational meaning and the whole classification clear. No significance, except one of convenience in description, is attached to the order of the groups as given.

It will be observed that the activities in each group begin early and continue through childhood; that they arise out of some hunger, instinct or innate capacity in human nature; that these same traits have given rise to some phase of racial life or culture; and that each group has some special value in the development and adjustment of the child.

(a) BIG-MUSCLE ACTIVITIES.

The big-muscle activities are fundamental to all others. They arise out of the primary hungers for activity; begin in the random movements of the infant; develop through the various stages of locomotion and diverge during childhood under the influence of special instincts into such special forms as gymnastics, games, dancing, and athletics.

(1) Gymnastic plays arise from the self-testing impulse. They are personal motor achievement plays and express the enthusiasm for self-realization.

(2) The dancing activities add pleasure in rhythm. They begin in spontaneous forms and take on traditional forms through imitation, developing the sense of rhythm, as well as the capacity for artistic expression in body movements. They also have deep social meanings and influences, especially during the adolescent years.

(3) Games and athletics arise from the hunting and self-protecting instincts and from the gregarious, egoistic, and fighting instincts which find expression in rivalry, and which have been such powerful forces in the rise of civilization. These instincts develop progressively in games of fleeing, chasing, hiding, seeking, capturing, and escaping, and later, team games of conquest.

These big-muscle activities are the developers of the organic powers and the fundamental nervous powers; i. e., they are the educational source of vigor, resistance to disease, and general nervous vitality and skill. They lay the foundation for (adult) capacity to labor. They establish wholesome forms of recreation. While regarded usually as mere muscular exercises or "pastimes," these activities, especially the games, carry the discipline of the racially old instincts at the foundation of character, and are therefore primarily instinct educators and fundamental in their influence on character development. They carry the "social spirit" and discipline the social instincts, emotions, and enthusiasm. Hence, in the education of children they must be given a large place and be guided carefully as the most important laboratory activities in the moral phase of education.

(b) MANUAL ACTIVITIES.

The manipulating and manual activities arise out of the manipulating impulse which satisfies the hungers for activity and sense experience. Gradually, under the influence of the "constructive" impulse, imitation, and self-expression, the various manual activities arise. These tendencies in human nature, coupled with needs for food, protection, and expression, have developed the industrial enterprises and graphic arts of man. In the child they begin in general manipulation, expanding along the lines of construction with blocks and miscellaneous materials; modeling, scribbling, drawing, coloring;

and then construction with tools in paper, wood, stone, and iron, and in plastic materials, textiles, foods, etc. When the child expresses esthetic feelings and ideas in these activities the manual arts appear. This manipulating impulse, combined with the social, gives a large number of plays and games. Each of these tendencies is represented in the complex occupations, crafts, arts, modes of expression, and recreations of the adult. They give the spontaneous beginnings of activities which, when developed, include a large part of applied science.

Under leadership the values of these activities in the development of nervous powers for manual skill, in the ability to think in mechanical terms, and to design and execute, in the expression of esthetic ideas and the development of esthetic feelings, and in the discipline of elemental traits of character, are well recognized. As Dewey showed, they may be organized to unite the individual's social feelings and thoughts with the industrial problems of the race. For the masses they underlie economic adjustment and industrial adaptability. They are important for the nervous, moral, and esthetic stability of the nonindustrial classes.

Leadership in these activities is needed from infancy to maturity, first for cultural education, then for vocational and recreative results. In this leadership, the ages between 7 and 10—the critical, yet most neglected years—when impulse and skill are furthest apart, need special attention.

(c) ENVIRONMENTAL AND NATURE ACTIVITIES.

Environmental and nature activities fall into two related classes: (1) Excursions and (2) nature experimentations. The instincts that have led to the world's exploration and to the development of the natural and physical sciences are here expressed.

(1) The excursions arise from the exploring, foraging, and migratory instincts, and arouse great enthusiasm. They begin with the creeping of the infant and continue all through environmental activities of later years. These excursions give some of the organic and nervous values of big-muscle activities; they develop the self-preserving instincts and powers; they give the opportunities for observation, the collection of information, and the satisfaction of curiosity concerning nature and civics. Leadership easily perfects the educational values in the spontaneous tendencies to these activities, as indicated in the following suggestions, which grade naturally by age periods.

For the little children, short trips give opportunities for broader "free play" activities in the environment, for a larger sense experience, for collections, for learning the names of natural objects, for simple observational games, and for instruction concerning things which catch the attention.

For the larger children, excursions cover the three ideas of adventure, nature observation, and civic observation, as follows: (*a*) Half-day "hikes" or week-end camping trips, including outing or "scouting" arts; (*b*) trips to the fields, woods, and bodies of water, or to farms, or to plant or animal experimental stations; with observations on the geographical features, on plants and animals and their breeding processes; with collections, maps, etc.; (*c*) trips to industrial and commercial institutions, to historic places, to civic institutions and centers, to public-service centers, etc., each with investigations. From these natural activities the larger geography expands.

(2) The second half of the environmental and nature activities, nature experimentations, arise from curiosity about nature and the experimental manipulation of natural forces. They fall into three groups: (*a*) There is playing and experimenting with physical nature,[1] namely, playing with water, air, heat, mechanical devices, sound, light, and electricity. These activities begin in the same manipulating tendencies that are the foundation of the manual activities, but diverge under the control of different instincts. They grade naturally by age periods and through leadership develop problems in physics. (*b*) There is playing and experimenting with animals: namely, playing with pets; feeding and caring for animals, training them; capturing, raising, and taming wild animals; breeding animals, etc. (*c*) There is playing and experimenting with plant nature, namely, planting, raising, and caring for plants and flowers; experimental gardening to find out what nature will do and also for the economic value of the produce.

The two latter groups of nature activities with the field observation and collections give all the essential elements in the relations of plants and animals to the life of man, and give, through leadership, the natural basis and enthusiastic interest in the problem of nature study and "civic biology."

The specialized sciences have no place in child life. These nature activities give what is natural to child life and interest and lay the foundation for a more advanced study later.

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[1] The content of these physical experimental plays will be better illustrated by the following outline: Water: Playing with water, pouring, wading, splashing, watching objects in water, throwing objects into water, building dams and water wheels, watching the action of water on land, "erosion models," etc., which develop problems in fluids. Air: Playing with air, sailboats, kites, windmills, aeroplanes, which develop problems in air pressure, air currents, wind, temperature, humidity, rainfall, etc. Heat: Watching fire, making fires, observing friction and heat, playing with toy steam engines, thermometers, which develop problems in heat, combustion, expansion and contraction, and other effects of heat. Mechanical devices: Playing with hoops, tops, pulleys, wheels, toy machines, gyroscopes, pendulums, levers, watching thrown objects, balancing objects, etc., which develop problems in motor dynamics. Sound: Vocalization, beating and drumming, blowing on toy instruments, "listening to shells," speaking tubes, and telephones, experimenting with conduction through air, water, and timbers, with vibrating bodies, echoes, etc., which develop problems in vibration, noises, tones, music, etc. Light: Playing with reflectors, mirrors, prisms, lenses, water refraction, glasses, telescopes, which develop problems in light, color, optics, time, etc. Electricity: Experimenting and playing with magnets, batteries, induction coils, telephones, telegraph instruments, dynamos, electric motors, electric lights, etc., which present problems in electrodynamics.

(d) DRAMATIC ACTIVITIES.

Dramatic activities arise out of the imitative and dramatic tendencies and the hungers to experience the form and content of conduct, and express environmental situations. In the adult these tendencies and hungers have developed the dramatic arts. In the little child, dramatization intensifies ideas and bears the same relationship to an appreciation of conduct that manipulation bears to knowledge of physical nature. The child interprets conduct through his own motor activities and later expresses an ideal. In all classes of children these activities grip the imagination. They correlate and give added zest to other phases of activity. Under leadership they plant rich associations that give immediate educational values and help develop the capacity for some of the higher recreative arts in the adult.

Leadership for the little children should supply opportunities for a broad range of imitative dramatization of single, social, and environmental situations. For the larger children, leadership should be given in the dramatization of social situations, in the construction of plots from stories and history, in the use and adaptation of plays, and in the development of simple pageants. These latter forms of dramatization will lead toward the celebration cf holidays.

(e) RHYTHMIC AND MUSICAL ACTIVITIES.

Rhythmic and musical activities arise out of vocal and manual experimentations and the pleasures derived from rhythm, tone, and melody. These pleasures, with their emotional relationships, have created the musical arts of man. In the child, rhythmic and musical activities begin in crude vocalization, bodily movements, and drummings, and develop through various stages of complexity. There are (1) bodily rhythms, as running, stamping, marching, skipping, etc., up to dancing; (2) vocal rhythms and tones, as counting, repeating sounds and tones, leading up to poetry and singing; (3) drummings and beatings with sticks, fingers, or cans, picking sounds on strings and blowing sounds on bottles or shells, leading up to the use of drums, cymbals, and string or wind instruments.

These are all music activities to the child, but the music of the race is highly evolved, and it has a complex written language. It is a simple matter to organize the musical activities characteristic of each age period, but the transition to the musical activities of the racial type or to an appreciation of these is achieved for the masses only through a broad association or skilled leadership. Individuals differ enormously in musical capacities. All children should have their musical impulses developed to the point of adjustment in the community social recreative life.

In the transition three methods of leadership or instruction are possible: (1) The natural musical activities of the child may be organized and led into the racial type; (2) the gap may be bridged through play methods of instruction; or (3) music may be interpreted as a formal subject of study that can be taught only by formal methods under the discipline of instruction. The last is the traditional method and is essential for any advanced skill. The second method secures results, especially with the little children. The first method is used frequently in boys' clubs and in the organization of children's orchestras.[1] It has been highly refined on one side for training in rhythm by Dalcroze.[2] This method has back of it the power of instinct; it opens the channels of natural development to leadership; it can be supplemented by all other methods as desired.

(f) SOCIAL ACTIVITIES.

Social activities arise out of the social instincts and hungers. These instincts have amalgamated all human instincts for the development of society. Their expression in the child gives social experience and they frequently take the form of experimentation with human nature.

The play school is a child's social center. In addition to the social life involved in each group of activities, there is a general social life and spirit. All the social relationships of the special activities are looped up in this larger social unity. It involves all human relationships in the school and it radiates into the social environment and the home. In these activities are expressed all the impulses of developing human nature in social relationships. Social attitudes, habits of speech and manners of address are developed which contain many inconsistencies and conflicts, and which change in emphasis and importance by age periods; but fuse gradually into a system of ways of acting that determines the adult's social adjustment. In addition, there are the developing ideas and habits in the relationship of boys and girls, that differentiate during the adolescent years into sex habits and ideals and lay the foundation for adult domestic adjustment. Therefore in the general social life of the play school, and in the social life connected with each special group of activity conduct must be guided by each leader according to accepted social standards of individual and group fair-play, good humor, courtesy, justice and common sense, yet ideal social relationships. The foundation for social and citizenship adjustment, sex hygiene and domestic adjustment must be established in this leadership.

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[1] See Dykema, in Chubb, Festivals and plays in school and elsewhere.

[2] Sadler, M. E., The Eurhythmics of Dalcroze.

A special social hour should be organized to coordinate the social side of the activities and to give the opportunity for establishing democratic ideals. From this the leadership should extend to the spontaneous group organizations in and out of the play school.

(g) VOCAL AND LINGUISTIC ACTIVITIES.

Vocal and linguistic activities arise from the vocalizing and communicative instincts. These instincts are the primary elements in the evolution of the languages and the literatures of the world. In the child, these activities begin in vocalization and develop through imitation and the need for communication into the vernacular.

Linguistic activities are associated with each group of activities. The child tends to vocalize his thoughts and feelings. He is the great questioner. Conversations arise. Thus he develops language as a tool and elaborates a system of ideas. Both these tendencies should be perfected through leadership. Language is the tool of knowledge and rational adjustment. Conversation consciously developed through sympathy or elicited and directed, is the method that gives progress in language power, thought and systematic information, and carries with it the living motive.

In the activities interests develop that, under leadership, are expressed in narratives and discussions, and these are the opportunities for mind "fertilization," as well as the elevation of experiences to the level of general ideas and conscious understandings. These conversations are also distinctly language lessons and should be guided carefully as such.

With the development of the activities and interest under leadership, the need arises for a written language and it should be taught at this time. When gained as a tool, it should be used, not in reading unrelated stuff, but in connection with the activities as a source of information, and as a real phase of living.

For the little children, story-telling of a rational kind should have a prominent place and later this function should become supplementary in helping the individual select stories to read, that are adapted to his needs. It has been demonstrated that leadership will bring children to the realization that there is a literature to cover each interest and satisfy each desire in life.

Numbers for the child are a linguistic activity and should be developed in connection with his games and later manual and environmental activities.

The absorption of a foreign tongue, naturally by its use in play, is another phase of these linguistic activities, and when the environment makes it desirable can be easily brought about.

(h) ECONOMIC ACTIVITIES.

Economic activities arise out of organic hungers, the acquisitive impulse and economic needs and desires. The child is dependent and gains his economic adjustment through the family, but the necessity of labor to produce wealth and of paying others for wealth desired is ever present, and frequently arouses economic activities which need guidance. So leadership should be given in earning money by service or effort that produces economic values. The organization of vacant-lot gardens and leadership in marketing produce is important. The opportunities for house and yard repairs at home and in the neighborhood need leadership. Taking contracts, with the figuring of materials, cost and profits, are frequently possible even among children. Banking, the use of the United States postal savings depositories, and personal bookkeeping are phases of these activities. The dramatization of store and house with buying and selling familiarizes the child with the social forms of exchange.

SUMMARY.

If the analysis of the several classes of activities as given is practically correct, then we have a natural grouping of child activities susceptible of practical organization and administration for efficient educational results when considered from any standpoint of educational theory or practice. Criticism and continued experience will doubtless dictate some changes, but the classification shows at least the possibility of organizing several groups of activities:

(1) That include all the spontaneous and traditional tendencies in child life.

(2) That express, in child form, the human tendencies that have created civilization.

(3) That retain in natural and related forms the germs and expanding lines of every subject of interest that has arisen with adult civilization.

(4) That give the opportunity for so directing the child's living forces, that he will expand naturally according to his capacities into an inheritance of some part of the race achievements.

(5) That meet the demands of every aim of education whether of development or adjustment, and therefore that relate the claims of physical, moral, vocational, and cultural education.

(6) That simplify the problem of cooperation between the play-school center and the home.

(7) That present the basis for a school program which will not devitalize children who are subjected to three or four hours of it, and may be extended to the whole waking life for 365 days in the year, making every child physically, intellectually, and morally stronger.

SKETCH OF THE LIFE OF EDUARD SUESS (1831–1914).[1]

By Pierre Termier,
Of the Paris Academy of Sciences.

Eduard Suess, member and former president of the Imperial Academy of Sciences of Vienna, dean of the foreign associates of the Paris Academy of Sciences, peacefully and painlessly passed away on the night of the 25th of April, 1914, in Vienna, at the age of 83 years. His death is mourned by the geologists and geographers of the whole world, for all looked upon him as a master, whose authority was supreme and whose intuition was well nigh infallible; and there is not one among them who has not in some way been his disciple, and who has not received from this man of genius with his clear ideas and his exact method the taste for profound problems and the enthusiasm indispensable to persevering researches.

He was born on the 20th of August, 1831, in London, of a Jewish family, then recently come to England from Austria and who soon returned to that country. His father was a trader, a willing wanderer, like so many others of his race. Indeed, if one would understand Eduard Suess, this origin must never be forgotten. He was the man called to show and explain to us the face of the earth; to lead us, as by the hand, along all the shores and in the labyrinth of all the mountains of this planet; to make of us citizens of a humanity greater than all the nations and more enduring than all histories; this man was a splendid type of that old race, that nation elect, to whom universal supremacy was at one time promised, and whom we now see wandering without respite along sorrowful ways, moving across the continents and the oceans of the earth.

The young Eduard studied first at Prague, then at Vienna, and very early attracted attention through his taste for the study of fossils, minerals, and rocks, a study which soon became an irresistible passion. In 1852, then only 20 years old, Eduard was appointed assistant at the Hofmineralenkabinett in Vienna, a kind of practical school of geology and mineralogy installed in the buildings of the Hofberg; his scientific career was begun. A first note on the Graptolites of Bohemia appeared in this same year, 1852. In 1854, he published a memoir on the Brachiopods of the Kössen beds, and in 1855, a study on the Ammonites of the Hallstatt beds. This was a very decided trend toward paleontology, and even toward the most philosophical paleontology, that which seeks to reconstruct the filiations of living beings and to learn the laws of their mysterious evolution.

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[1] Translated by permission from Revue générale des Sciences pures et appliquées, Paris, June 15, 1914.

In spite of the brilliant qualities which shone in his first essays, the University of Vienna did not appear at all eager to open its doors to the new paleontologist; and the difficulties he encountered while seeking his doctorship more than once very nearly discouraged him, and almost led him to enter commercial life where his family would have been happy to have placed him. Success came, however, in 1857, and Eduard Suess was designated professor extraordinary of paleontology at the university. He retained this position until 1862. The death of Zippe having at that time made vacant the chair of geology, Suess succeeded him at first as professor extraordinary, then, in 1867, as professor ordinary. The paleontologist was transformed, little by little, into a geologist; and this geologist successively preoccupied, with local stratigraphy in the immediate vicinity of Vienna, then with Alpine stratigraphy, was later to turn to the Alps and by the prolonged contemplation of this great chain of mountains, to become a master of structural geology, and a little later the uncontested master of all geology.

Eduard Suess possessed in an extreme degree the qualities which make the professor worthy of the name, and even those accomplishments which make great orators; his nobility of presence, the beauty and solemnity of his features, the softness and warmth of his voice, the ease of speech and abundance of imagery; the continual tendency to soar in lofty flights to the summits of his philosophy, into those high regions above the clouds where the noise of human conflict does not reach; the gift of animating all he touched, and, by the splendor of form and enthusiasm of utterance, of making ideas and objects live; finally, the love of conquering, of instructing, of increasing his own store of knowledge, and of fully engaging his audience. From the very first year of his course the professor became celebrated. People crowded the amphitheater; they followed him on excursions which he directed to the environs of Vienna. His reputation extended throughout the whole city. His book on the Viennese subsoil, "Der Boden der Stadt Wien," appeared in 1862, revealing a new way of considering geology and of connecting it with human geography and sociology. In the same work were considered the relations between the formation and composition of the subsoil and the life of the citizens. This book soon passed from the confines of science into the midst of average culture and decided the political career of Eduard Suess; for he had two careers running parallel, one devoted to the highest and most disinterested science, the other, that of an ardent citizen, a passionate defender of municipal interests and political liberty. It was in 1863, less than a year after the publication of "Der Boden der Stadt Wien," that he entered the municipal council of Vienna where he remained for 10 consecutive years. Resigning in 1873, he returned to it in 1882, not to leave the council definitely until 1886. In 1873, he had been elected deputy; and for many years he was in the Austrian Chamber, one of the orators of the left, one of the most resolute adversaries of the ultramontaine party, one of the leaders of the liberal party, the Fortschrittspartei.

It is difficult to believe to-day that the man who in 1875 wrote "Die Entstehung der Alpen," and from 1878 to 1883, the first volume of "Das Antlitz der Erde"—those books whose principal characteristic is their calmness—is the same man who simultaneously became excited in parliamentary contests and startled his adversaries by the vivacity of his attacks and his quick repartee. The identity of the great scholar and the man of politics reappears, however, in the speeches of the latter. At all times—say those who have heard him in the chamber—his eloquence aroused in him a sort of poesy, without analogy or precedent, a poesy in which are seen to pass in review the earth and its inhabitants, in which are heard chords of universal harmony. Thus, for example, he compared the abrupt dawn of glory and influence of the old English universities to the sudden appearance in the sky at a point until then hidden from the constellated firmament, of a new star, such as Mira Coeli, whose light, although unsuspected, existed, nevertheless, for centuries, and proceeded toward our gaze in fathomless space. Sometimes, wishing to speak of the train of great thoughts and worthy ideas which travel from nation to nation bettering mankind everywhere, he described to the astonished and mute assembly that isolated reef at the extreme tip of South America, where navigators have placed a cask, sheltered by no pavilion, and belonging to no one. Each ship that passes sends off toward this desolate rock a little boat and the sailors who climb its sides place in the cask letters addressed to their native lands, and from it take the letters which they find there bearing the address of the countries toward which they are bound. The sailors' letters thus wander about from port to port without being directed by anyone and they proceed slowly but surely toward their distant goal. Full of such figures, this manner of speech belongs to Eduard Suess; it is his style; and never was a style more personal than his.

In the memory of the Viennese the name of Eduard Suess will ever remain connected with two great municipal works: The introduction of drinking water and the regulation of the flow of the Danube. They still say in Vienna, "Suess's water," when to a stranger they praise the purity and freshness of the water used in that great city, and which since 1873 has replaced the unwholesome water of the Danube and the lakes. That is justice to Suess, for it was he who first indicated the sources which were advisable—the mountain springs come to light in the Alpine region not far from Schneeberg on the borders of Styria and of Lower Austria—and he it was who strove with tireless energy from 1863 to 1866 before the municipal council for the adoption of that project. It required seven years to complete the work, and it was on the 24th of October, 1873, that the new water commenced to flow and was greeted by the joyful cries of the people of Vienna. The good people had indeed reason to applaud; the mortality in the city was almost abruptly diminished by one-half. The regulation of the Danube was achieved in 1875 by opening a new river bed from Nussdorf to Stadlau. In the eyes of Suess this was but the very small beginning of a gigantic project, through which the Danube was one day to be set right across the whole Empire from Passau to the Gates of Iron; but this beginning, due to Suess more than to any other man, was of great benefit. It protected the life and property of the inhabitants along the banks of the river, bringing to the center of the capital the most beautiful river route of Austria and permitting the creation and development all along the regulated bed of the river of a new faubourg, built and equipped for commerce and industry.

Even after retiring from affairs, and until the last years of his life, Eduard Suess continued to be interested in municipal and political struggles. He remained always the citizen of Vienna, with all the force of the beautiful word "citizen." On the last night of every year he was accustomed, with some political friends, to make a pilgrimage to the Reichsbrucke, and there, above the muddy waters that flowed past as the years roll on, to drink a glass of wine to the glory and prosperity of the city, his city, one of the first objects of his thoughts. But, then, who could say how his thoughts were divided—what fraction went to the city, what other to the Empire, what to the earth, and what to humanity?

Contemporaneously with his political career, the scientific career of Suess developed, just as brilliant, just as fecund, it seemed, as though the first had not existed. In 1866 he published a memoir on the Loess; in 1869, his "Remarks on the salt deposit near Wieliczka"; in 1871, a study on the tertiary continental faunas of Italy; in 1872, his book on the structure of the Italian Peninsula; in 1875, his "Die Entstehung der Alpen" (Origin of the Alps); in 1877, his considerations of the earthquakes of southern Italy and a little brochure, "Die Zukunft des Goldes" (The Future of Gold). From 1878 on he commenced the writing of "Das Antlitz der Erde," and this was a labor uninterrupted for 30 years. He remained professor of geology at the university until 1901, or a total of 39 years. In 1901 he asked for retirement. At first replaced by Uhlig, one of his best pupils, yet after the death of Uhlig he had the consolation of seeing his own son, Franz-Eduard Suess, take possession of this same chair. The incomparable joy of being succeeded by a son who continues the work of the father and who is known to be worthy of so doing, that joy known to but few men of genius, was not refused him.

He had been a member of the Imperial Academy of Sciences for a long time when in 1893 he was made its vice president. In 1899 he was elected president of this illustrious company, and kept that honorable position for 12 years. Named correspondent of the Academy of Sciences of Paris in 1889, he took his place, some time in 1900, among the foreign associates, succeeding Frankland. Honors came to him in proportion as his authority and reputation increased; the man himself remained modest, indifferent to titles, disdaining riches, voluntarily bound to a family life, austere and simple, his soul shut to personal ambitions, open only to noble ideas, to the disinterested cultivation of science, to the love of his fellow citizens, and of all mankind, to the tender affections which are born and cherished in the atmosphere of the domestic hearthstone.

An admirable life, deserving of happiness, and which indeed attained it in the measure at least in which a man of such great comprehension can be happy. Eduard Suess knew the ineffable sweetness of a peaceful life, in the midst of a numerous and closely united family. This existence had its hours of sorrow, but these do not come without consolation and never bring with them despair. He saw his six children grow up around him and later numerous grandchildren, and in his family circle, delightfully intimate, when he ceased to work, to think, to teach, when he stopped to chat or smile, he had only to lend ear to the rumblings from without. Among these rumblings, some no doubt the inarticulate sounds of the great city, came one sound which he well knew, for he had heard it from his youth, the sound of praise. An honor discreet and lasting, the gift of universal acclamation, accorded by the unanimous admiration of all who cultivated the same science, were interested in the same problems and had the same ideal; an appreciation expressed constantly by the receipt of an enthusiastic letter, a book bearing an inspired dedication, a visitor who presented himself with the pious and grateful attitude of a pilgrim, full of love, at the shrine of some sanctuary of former times.

The end was worthy of the entire life and lingered serene and splendid like "the twilight of a beautiful day." Until the spring of 1913 the aged master enjoyed good health and old age, which never affected his intelligence, touched his physical strength but timidly as with regret. His age was betrayed only by hesitation and difficulty in walking. Once seated, he seemed as he was ten or a dozen years before, almost young in appearance with his beautiful grave fa little pale and his magnificent eyes where one could almost see reflection of the illimitable oceans, and which looked, tender and of feeling, into the depths of one's soul. He spoke with a deep, pressive, richly modulated voice, in which the glow of former int or high-wrought emotions was extinguished, and there remained hushed sonorousness and quiet feeling. Then around the circl his listeners a murmur would pass and they would give their c attention, fearing lest they lose a word, an accent; they would h wished to fix this instant of inestimable value in the passage of t which, alas, never stops. Thus we see him in 1903 at the Geolog Congress in Vienna, keeping aloof from the sessions and off receptions, but willingly receiving his friends of every country a marked predilection for his friends of France. Thus we see again nine years later in August, 1912, at Innsbruck, come from Hungarian village expressly to preside at the reunion of the geolog of the Alps, at the principal function of the excursion organized the Geologische Vereinigung. This was the last manifestation of scientific activity. Is it not fitting that this last effort was made the author of "Die Entstehung der Alpen," on behalf of the geol of the Alps and in the presence of the investigators through wh the Alps have become better understood? Before this time, in 1 Eduard Suess had sojourned several weeks in the Basse-Engad and from this trip of 1905, the last in which he had been able to m excursions on foot among the rocks themselves, hammer in ha and to make personal observations, he made announcement of full and entire compliance with the doctrine of great "nappes recouvrement," or overthrust, a compliance soon formulated in a to the Academy of Sciences of Vienna, "Das Inntal bei Naude and affirmed more briefly still in 1909, in the last volume of " Antlitz der Erde." Now, in 1912, controversies had ceased and reunion at Innsbruck, gay and fraternal, had a character alm triumphal. * * *

Now, in the soil of Hungary, in the cemetery of the little tow Marczfalva, repose the mortal remains of Eduard Suess, until day when the angel—

> * * * swinging open the gates,
> Shall, faithful and joyous, make gleam again
> The tarnished mirrors, quicken the dead flames.

The Hungarian plain has become the tomb of him who so m loved and so well understood the mountains. But the Alps are far off; they cut across the horizon; and indeed we know tha their mad journey toward the Carpathians, their waves of stone pa even here. The place is, therefore, not ill chosen to shelter the of the man who was the incomparable singer of all these things. Neither the steps nor the cries of the living come to trouble the sleep of the master. From time to time, however, a geologist will come, who, full of respect and gratitude, will meditate before the solitary slab, praising God for having instilled so much grandeur and such a reflection of his divinity into the souls of the giants of the human race.

I have cited above the principal works of Eduard Suess. It is necessary to add to the list I have given many short notes and articles on different subjects: Tectonics, comparative geology, volcanoes, seismology, questions on the origin of meteorites, the question of the composition and the structure of the moon, the question of the recent displacement of the coast lines, and many others. The majority of the notes were published in the "comptes rendus" of the Academy of Vienna; the articles almost all appeared in the Neue Freie Presse, of which Suess was for a long time one of the scientific chroniclers. But that which is essential in both is found in the last chapters of "Das Antlitz der Erde." Among the colossal labors of Eduard Suess, those which immediately attract attention, those which will endure for an indefinite time on their own merits without becoming obsolete, to preserve for centuries the glory and majesty of the beautiful ruins, are the two books, "Die Entstehung der Alpen" and "Das Antlitz der Erde."

"Die Entstehung der Alpen" is a small work of 168 pages, published in Vienna in 1875, composed of 8 chapters. The author brings up and defends the idea that in the formation of mountains the preponderating rôle is played by horizontal displacements, moving in one direction. Each chain is a whole, thrust from the same quarter over the preexisting formations, which resist, and on which the compressed zone advances. There is but one cause which has produced the whole Alpine system; this cause is a thrust from the south or southeast. Characteristics analogous to those of the Alps are manifested in the Balkans, in the Caucasus, in the chains of the American northwest. * * * Each chain is the work of a very long period, and its formation is the sum of a multiplicity of occurrences. The author insists on the coincidence of the Alpine zone with geosynclines. He remarks—and no one before him had cared to do it—on the magnitude and the generality of certain marine transgressions; for example, of the Cenomanian transgression. He foresaw the periodicity and the quasigenerality of transgressions and recessions. In the next to the last chapter he invites us to make with him the tour of the earth; he shows us in Europe and in the east of northern America the predominance of thrusts toward the north; he calls our attention to those immense regions of the surface of the earth which seem refractory to folding, and which are traversed by fissures whose direction almost follows the meridian; he makes us see that in central Asia the overthrust of the chains is usually toward the south. The conclusion of this rapid journey around the globe is that in terrestrial deformation there is no simple geometry; that the mountains result from the irregular and unequal contraction of a planet devoid of homogeneity; finally, that this lack of homogeneity goes back to the period of consolidation of the lithosphere. It could not become hard all at once; it presented for a long time the appearance of an archipelago of scoriaceous masses floating on a fluid and incandescent sea. The earth was then a variable star.

The influence of the book was great. It was short, readable, perfectly clear; it revealed a new geology, unsuspected, immediately accessible; it is written in language simple and beautiful. * * * It has directed young geologists of every country toward the study of the mountains; it definitely destroyed the old theories. It substituted, in the minds of all geologists, for the principle of direction the principle of continuity; it accustomed investigators to the idea of transportations of strata; it fixed attention on the great movements of advance and of retreat of the sea. In a word, it was the preface of "Das Antlitz der Erde," the prelude of that incomparable symphony.

"Das Antlitz der Erde" is an essay on geologic synthesis, extended to cover the entire earth; and it is the first essay of its kind. The work, of gigantic dimensions, comprises three volumes. The first appeared in 1883; the last part of the third in 1909. Twenty-six years were required for the complete achievement of this magnificent work. It is well known that by the care of M. Emmanuel de Margerie the entire book has been translated into the French language and published in Paris under the title, "La Face de la Terre." The last part of the third volume of this French edition is at present in press.[1] "La Face de la Terre" is enriched with notes, maps, and cuts, added by the translator, which happily supplement the text and illustrations of the German edition.

The general plan of "Das Antlitz der Erde" will be recalled. The first volume comprises two parts—the movements of the outer crust of the earth and the mountain ranges. The second volume is given to the third part of the work, the oceans. The third volume, much more voluminous than the first two, embraces the fourth part, which is the detailed study, not only geographic, but also, and especially, geologic, of the face of the earth. The first half of this third volume is composed of 9 chapters, in which the author describes entire Asia, and northern Europe. The second half comprises 18 chapters, in which are delineated, first, the rest of Europe, the east of northern

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[1] This volume has since been issued.

America, the chains of northern Africa, the old Laurentian continent, the immense African Plateau, and the chains of the Cape, the chains of the islands of Oceania, the mountain systems which extend the length of the west coast of the two Americas; followed by general considerations on folds, on the depths, on the manner of formation and the distribution of volcanoes, on the moon and recent geologic theories, and, finally, observations on life.

The book is an exposition of the planet viewed from without, as travelers from other stars of the solar system would see it. It contains scarcely any theories. The author does not seek to explain or to convince; he shows. He leads his reader by the hand; he makes him see the peaks and the abysses; he makes him touch the seams and fractures with his hand; he leads him along the shores, not only those of to-day, but also those of the ancient seas; and he goes over with him step by step the traces, three-fourths effaced, the wrinklings, the foldings of former times. In the company of the master one soars on geologic time as on the air of this earth. The impression is singular, immediate, unforgettable; one knows no longer, indeed, at what epoch in the duration of time, life came on this earth; and there are seen, sketched simultaneously on the face of the planet, the ancient features and the present features. A vision, giddy, often confused and troubled, like those which pass, on a high mountain, under the eyes of the Alpinist, a day of heavy cloud and violent wind; "a vision a little cloudy, a little sybilline, in which there are mist and clearness, thunder and great silence, diluvian floods and sun-fêtes, days and nights of inordinate length, and which recall "A Legend of the Centuries," in which man was lacking.

The usefulness of such a book is to arouse great and growing enthusiasm and to create an interest in this luminous science through all their lives among hundreds of young men who without that incentive would have done nothing or would have groped about in the dark, to enlarge our thoughts, to give us the taste for general problems and the thirst for synthesis. It can be said without exaggeration that Eduard Suess had his part, often a preponderating one, in all the geologic discoveries of the end of the nineteenth century and the first years of the twentieth. The geologic sciences, which have advanced with giant steps for 30 years, would not without him have advanced so rapidly. He did not say all, he made few personal observations, he did not foresee everything—but by his intuitions, truly those of a genius, of relations and their causes, he incited, prepared, made possible decisive observations, observations which have revolutionized our ideas and illuminated our knowledge. Among the most important discoveries, among all those which have changed the aspect of geology, there figures in the first rank the verifying, in mountain chains, the structure in great nappes, which makes of these mountains immense piles of strata misplaced and drifted. This discovery is not of Eduard Suess—if it is of any one man, that man is Marcel Bertrand [1]—but who would have dared, even dream of it, before having read "Der Entstehung der Alpen" and the first volumes of "Das Antlitz der Erde"? And when Suess in the chapters of Volume 3, which he consecrated to the Alps, adopts in his turn this manner of seeing, and speaks of the Helvetian nappes, the Lepontine nappes, the Austro-Alpine nappes, thrown one on the other, this theory so new and so audacious, seems to spring spontaneously and naturally from what he taught formerly.

Genius never lacks detractors. The author of "Das Antlitz der Erde" has often been criticised and cried down. One of the bitternesses of his life was the incomprehension and ingratitude of some of his pupils; one of his consolations, on the other hand, was the immediate and lasting success of his book in foreign lands, and especially in France. He has been reproached on the score of obscurity and lack of preciseness; but this lack of clearness and preciseness is usually, in the nature of things, the result of the imperfections of our knowledge, of the insufficiency of observations, of the difficulty of the problems confronted. "When Suess affirms," as I said in 1910, in reviewing the last volume which had just appeared, "one is quite certain that he does not deceive; when he is unprecise, it is because preciseness at that time is impossible; when he is obscure, it is because he has not yet understood, and because he finds obscurity preferable to the clearness of an illusion created complete in all its parts by his imagination." His splendor of style has been reproached, and, as it has been called, his geopoesy, as though the writer of genius were master of his tongue, as though the eagle could flutter about after the manner of a barnyard fowl. Finally, he has been reproached with not taking sides in the warmly controversial questions, with preserving an indecisive, timid attitude, by which was shown his embarrassment. This last reproach would be grave enough if addressed to a theorist; but Eduard Suess was never a theorist. This man once accustomed to teaching and to conquering, ardent also in political disputes, had for a long time ceased to argue on scientific matters; he was content with seeing, and after having seen, with showing. No mind has been more intuitive, or more exclusively intuitive than his. * * *

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[1] "The concept of overthrusts in the Alps was first described in detail by Albert Heim and later developed by Marcel Bertrand; but neither of these geologists was the author of the idea of the great overthrust sheets, which owes its at present accepted form to Maurice Lugeon."—Bailey Willis.

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